WATER, LAND, AND RELATED RESOURCES

NORTH COASTAL AREA of CALIFORNIA
and PORTIONS of SOUTHERN OREGON

APPENDIX NO. 1

SEDIMENT YIELD and LAND TREATMENT

EEL AND MAD RIVER BASINS

JUNE 1970

Prepared by the

UNITED STATES DEPARTMENT OF AGRICULTURE
RIVER BASIN PLANNING STAFF
SOIL CONSERVATION SERVICE FOREST SERVICE

In cooperation with the

CALIFORNIA DEPARTMENT OF WATER RESOURCES

USDA-SCS PORTLAND, OREG. 1970

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- U. S. Department of Agriculture,
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- Mendocino County Farm and Home Advisor's Office (Agricultural Extension Service)
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- Pacific Gas & Electric Company
- University of California, School of Forestry and Conservation
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APPENDIX NO. 1

SEDIMENT YIELD AND LAND TREATMENT

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S U M M A R Y

The California Department of Water Resources requested a reconnaissance-level study of sources and causes of the high sediment yields in the North Coastal Area and an assessment of the ability of existing USDA programs to solve the problems identified by the study. This study[1/] is being made in conjunction with water development studies of other Federal and State agencies.

The Eel River Basin (3,905 square miles) has its headwaters in the Mendocino National Forest near Lake Pillsbury and flows northwesterly, draining portions of Mendocino, Humboldt, Trinity, Lake, and Glenn Counties and eventually entering the Pacific Ocean about 15 miles south of Eureka, California. Its major tributaries are the Middle, South, and North Forks of the Eel River and the Van Duzen River. The Eureka Plains are also included.

The Mad River Basin (929 square miles) has its headwaters in the Six Rivers National Forest above Ruth Reservoir and also flows northwesterly, entering the Pacific Ocean about 10 miles north of Eureka. It drains portions of southern Trinity and central Humboldt Counties and has no large tributaries. The basin also includes Redwood Creek, which enters the Pacific Ocean 35 miles north of Eureka, and several intervening coastal streams.

The basins contain steep, mountainous terrain covered by unstable soils and have extensive flood plains near their mouths. Ample precipitation, although seasonal, combines with a mild climate and fertile soils to make the area highly productive when properly managed. However, the susceptibility of the area to soil erosion from natural causes and the tendency of landowners to accelerate that erosion through unwise land management practices, have combined to give the Eel River Basin a rate of sediment yield that is the highest known for any basin of comparable size in the United States. As far as is known, this rate is exceeded only by such world record holders as the notorious Yellow River of China (3.8 acre-feet per square mile per year) and certain of its tributaries (up to 10 acre-feet/square mile/year). The rate for the Mad River Basin, although only about two-thirds of that for the Eel, also constitutes a major problem.

This appendix presents the general physical characteristics and resources of the basins, such as topography, soil associations, geology, vegetal cover types, and land use and ownership. It describes the procedures used to investigate erosion, determine sediment yields, and formulate a land treatment program. Sediment rates are given for the various sources and causes, and possibilities for implementing the land treatment program are discussed.

1/ This publication is the first of two appendices to the report <u>Water, Land, and Related Resources--North Coastal Area of California and Portions of Southern Oregon</u>. This appendix covers the Eel and Mad River Basins and presents the results of the watershed management study. The other one will cover the remaining river basins in the North Coastal Area and will be followed by the final report.

Sediment yields for the Eel and Mad River Basins are summarized as follows:

Basin	Present Area Square Miles	Estimated Sediment Yield Acre-Feet/Year	Estimated Rate of Sediment Yield (Acre-Feet/Sq.Mile/Year)
Present			
Eel River	3,905	12,361	3.2
Mad River	929	1,984	2.1
Total	4,834	14,345	3.0
Future Without Recommended Program			
Eel River	3,905	13,152	3.4
Mad River	929	2,071	2.2
Total	4,834	15,223	3.2
Future With Recommended Program			
Eel River	3,905	10,503	2.7
Mad River	929	1,604	1.7
Total	4,834	12,107	2.5

Four sources of sediment were studied -- streambank, landslide, sheet and gully, and road erosion -- and were found to yield about 64, 25, 10, and 1 percent, respectively, of the total sediment. The major portion of the sediment yield was found to result from natural geologic erosion.

Land treatment programs recommended to reduce sediment yield fall into two general categories -- remedial measures and management guidelines. Remedial measures, such as streambank and landslide stabilization, were considered too costly for normal on-site benefits. However, many of the measures discussed may be economically justified in localized situations where high values are involved.

The only remedial measures that were found to be economically justified over large areas are those designed to reduce sheet and gully erosion on privately owned grasslands used for grazing. Seeding and fertilizing to increase vegetal cover and reduce sediment yield is recommended on 419 square miles of this land. Reforestation is recommended on 120 square miles of land previously converted from timber to grass. The average annual cost of these two programs is about $1 million for the 20-year installation period and $442,000 thereafter.

Under present policy and funding, USDA programs could accomplish only about 10 percent of the land treatment program recommended in this appendix. If USDA programs were to be accelerated, about 30 percent could be realized. Such acceleration would require increased funds as well as intensified informational efforts to interest more landowners.

To accomplish the entire land treatment program, it will be necessary to modify USDA programs so that specific needs of the basins can be fully met. Some proposed modifications are presented in this appendix. For complete success, it is essential that the full capabilities of all USDA, State, and local agencies be utilized and that the local people, particularly the grazing land owners, become deeply involved.

Alternative solutions are presented in the form of ideas for new programs and legislation that could successfully accomplish the program.

GLOSSARY

The following terms appear periodically through this appendix and are defined here to avoid repetition:

BEDLOAD -- The sediment that moves by sliding, rolling, or bouncing on or very near the streambed; sediment moved mainly by tractive or gravitational forces or both, but at a velocity less than that of the surrounding flow.

DEBRIS SLIDE -- Involves natural soil, unconsolidated sedimentary material, and weathered rock and is usually limited to material that overlies firm bedrock.

EARTHFLOW -- A slide that may have slow or very rapid movement. Usually the front of the mass bulges and advances as a more or less fluid tongue, and its toe, or lower portion, is bulbous in shape. An earthflow slide involves mostly plastic or fine-grained nonplastic material.

HIGHEST MEAN DISCHARGE for 7 consecutive days -- The mean of the discharges for the 7 consecutive days with the highest discharge in a given water year.

HYDROGRAPHIC UNIT -- Watershed areas that are convenient subdivisions of basins or subbasins. Except for the Middle Fork Subbasin of the Eel River, the hydrographic units are the same as the hydrographic subunits shown in the California Department of Water Resources' Bulletins Nos. 94-7, Land and Water Resources in Mad River -- Redwood Creek Hydrographic Unit and 94-8, Land and Water Resources in Eel River Hydrographic Unit (Sacramento, August 1965). The units are shown on the River Basin Map at the end of this section.

INFILTRATION -- The process whereby water passes through an interface, such as from air to soil or between two soil horizons.

PRESENT CONDITION -- The average condition for the 24-year study period (1941-1965). The 24-year period was selected because it was the longest interval between flights of the available sets of aerial photographs that could be compared.

ROCKFALL -- Rapid movement of rock that occurs on oversteepened slopes that have been undercut by streams or by roadbuilding. This type of slide is less common in the basin than the combination slump-earthflow variety.

SEDIMENT YIELD -- The amount of sediment carried past a given point.

SLUMP -- A form of landslide in which the movement is rotational. The top surface of the slide mass usually tilts backward toward the slope. Slumps usually involve bedrock as well as other material.

SOIL CREEP -- The process of gravitational mass movement whereby the soil and weathered mantle flows or moves slowly downhill due to the force of gravity.

SUM OF THE DAILY MEAN DISCHARGE for the 3 highest days -- The sum of the discharges for the three days with the highest discharge in a given water year. These days are not necessarily consecutive, but frequently are.

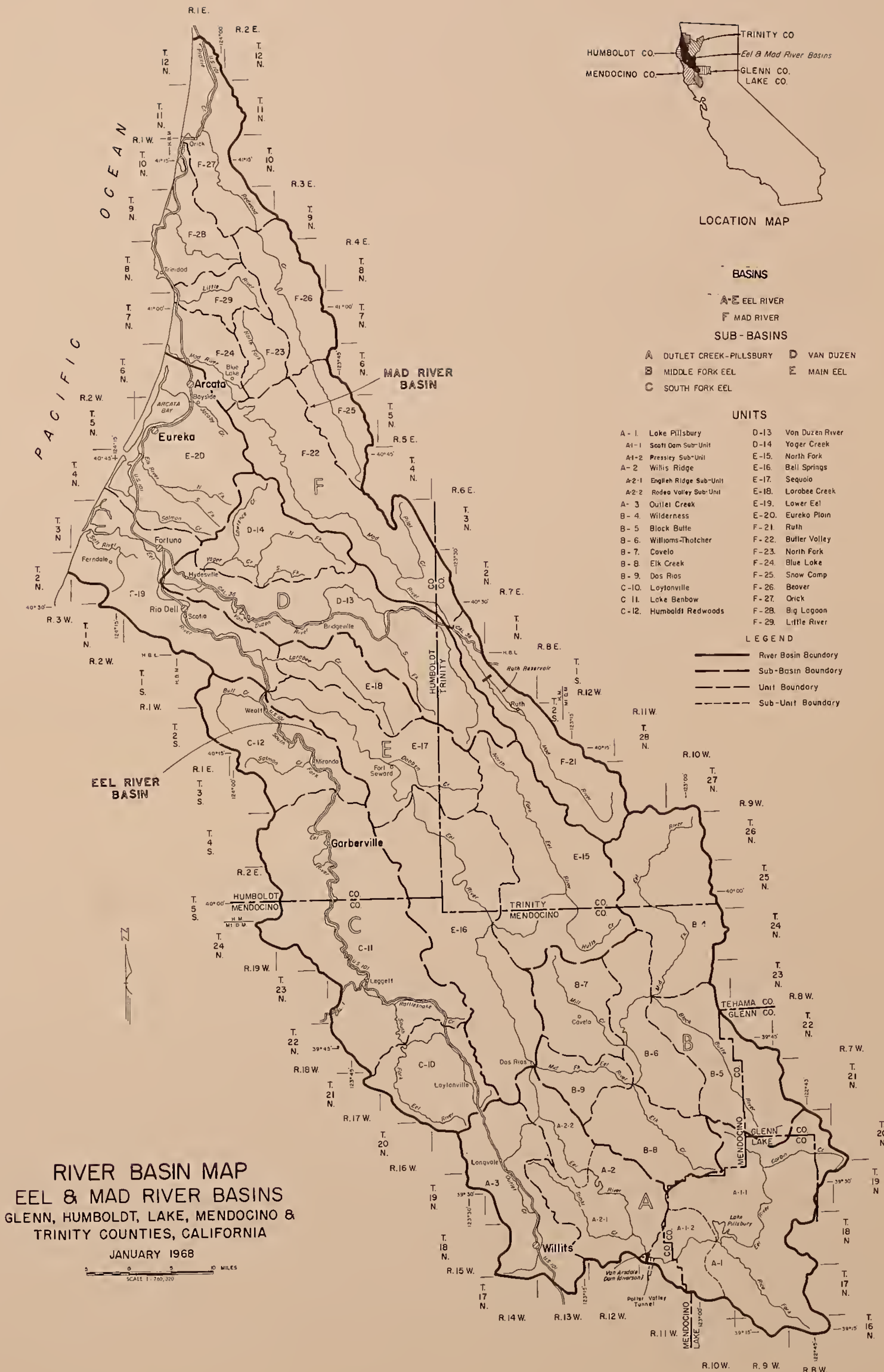
SUSPENDED SEDIMENT -- The sediment that is maintained in suspension by or that exists in suspension as a colloid.

WATERSHED -- All lands enclosed by a continuous hydrologic drainage above a specified point on a stream.

WATERSHED MANAGEMENT -- The analysis, protection, development, operation, or maintenance of the land, vegetation, fishery, and water resources of a drainage basin for the conservation of all its resources for the benefit of man. Watershed management for water production is concerned with the quality, quantity, and demand schedule of the water that is produced.

WATER TRANSMISSION -- That movement of water in the soil, which is controlled by the soil horizons.

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE



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INTRODUCTION

NEED FOR THE STUDY

An urgent mission of the California Resources Agency and its Department of Water Resources is the implementation of the State Water Project, a statewide plan currently financed to the extent of $1.75 billion as a result of the approval of the California Water Resources Bond Act by the voters in 1960. As a part of the implementation effort, the Department of Water Resources is conducting studies of land and water resources, beginning in the Eel River Basin and continuing in other basins of the North Coastal Area. These studies, when coordinated with studies of the U. S. Department of Defense, Corps of Engineers; the U. S. Department of Interior, Bureau of Reclamation; and the U. S. Department of Agriculture, are to provide a comprehensive and integrated plan for the North Coastal Area as a part of the State Water Project. It is intended that a program of large and small projects be prepared that will satisfy water needs within the basin and provide for the exportation of surplus water to satisfy needs elsewhere in the State.

Sediment yield is a major problem in the Eel and Mad River Basins, as illustrated by the fact that the Eel River carried over 100 million tons of sediment during the last two weeks of 1964. That flood produced record peak flows.

Economic development of these basins has taken place slowly and has not reached a high level when compared to other parts of California; unemployment has been high in parts of the basins, and four of the five counties are designated as eligible for a full financial assistance program under the Economic Development Administration of the U. S. Department of Commerce. Inaccessibility and remoteness from markets have been the primary deterrents to economic growth. With construction of better highways, now underway, this impediment is lessening.

Land management practices used by early settlers were often damaging to the watersheds, and present land use practices are causing watershed deterioration that appears to be detrimental to the general economy.

This publication is the first of two appendices to the report Water, Land, and Related Resources -- North Coastal Area of California and Portions of Southern Oregon. This appendix covers the Eel and Mad River Basins and presents the findings of the sediment yield and land treatment studies. The other appendix will present the same type of information on the remaining river basins in the North Coastal Area and will be followed by the final report.

The overall investigation covers the North Coastal Area of California, including all streams that drain to the Pacific Ocean from the Russian River in the South to the Smith River near the Oregon border. The portions of the Klamath and Smith River Basins in Oregon are included in the study area. The total area encompasses about 25,000 square miles, of which

about 19,500 square miles are in California and 5,500 square miles are in Oregon.

AUTHORITY FOR THE STUDY AND PARTICIPATING USDA AGENCIES

On March 11, 1964, the California Department of Water Resources requested the U. S. Department of Agriculture to cooperate with other State and Federal agencies in a study of the Eel River Basin. In the course of interagency deliberations, the Department of Water Resources extended its request to encompass the entire area of the North Coastal Basins. The Department of Agriculture agreed to participate in such a study under the authority of Section 6 of Public Law 566, as amended. The Department of Agriculture agencies that participated in the study are the Economic Research Service, the Forest Service, and the Soil Conservation Service.

OBJECTIVES OF STUDY

The survey had five major objectives:

1. To estimate the sediment yield by sources and causes under present conditions.

2. To estimate the future sediment yield under the expected use and management.

3. To formulate a land treatment program that would reduce the sediment yield and to estimate the costs of remedial measures.

4. To evaluate the physical effects of the recommended program.

5. To evaluate the potential development that could be obtained through U. S. Department of Agriculture Programs.

DESCRIPTION OF THE STUDY AREA

This appendix reports on the investigation of the Eel and Mad Rivers, Eureka Plain, Redwood Creek, and several minor intervening coastal streams. The Eureka Plain is included with the Eel River Basin, and Redwood Creek and the intervening coastal streams are included with the Mad River Basin. This study area of 4,834 square miles lies in northwestern California in parts of Glenn, Humboldt, Lake, Mendocino, and Trinity Counties (See the map at the beginning of this chapter).

INTERAGENCY COORDINATION

Coordination of the joint planning efforts in the North Coastal Area is provided by the California State-Federal Interagency Group, which consists of the California Department of Water Resources, the Corps of Engineers, the Bureau of Reclamation, and the Soil Conservation Service. Other agencies are represented through their membership in the technical subgroups of the Interagency Group. The objectives of the group are to facilitate coordination and cooperation among the various State and Federal agencies and to eliminate duplication.

Primary study responsibilities were assigned to the four agencies according to their major interests. The Department of Water Resources was assigned the responsibility for determining the state water requirements and providing the overall coordination for the joint planning efforts, the Corps of Engineers for flood control in the main stream and the major tributaries, the Bureau of Reclamation for irrigation water development at major projects and the development of hydroelectric power for inclusion into Federal power transmissions, and the Soil Conservation Service for watershed management studies and the investigation of flood control and irrigation projects in connection with U. S. Department of Agriculture Programs.

The Interagency Group will incorporate all the agencies' studies into a master plan for development of water and related land resources in the Eel and Mad River Basins, and a report is scheduled for publication in 1970. The main objective of the master plan is to improve living conditions of the people by enhancing the physical environment and improving the economic opportunities. Planning efforts for the complete development of water and related land resources will consider flood control, local water supply, water quality control, hydroelectric power, recreation opportunities, soil erosion reduction, improved watershed management practices, and the enhancement of fishing and hunting opportunities, and the export of excess water to the water deficient areas of California.

NATURE AND INTENSITY OF THE INVESTIGATIONS

Overall North Coastal Area investigations are being made at a reconnaissance level, with added emphasis placed on sediment yield problems. The intensity of the sediment yield studies was greater than that normally associated with a Type IV river basin survey. Watershed investigations were made to determine the opportunities for solving soil and water problems in the Eel and Mad River Basins through Public Law 566 projects. The full potential for development of these watersheds was the main consideration of the investigations; such development does not necessarily represent the desires of the local inhabitants. These investigations were made only in sufficient detail to assure that a project is feasible.

L A N D   R E S O U R C E S   A N D   U S E

Information regarding geology, soils, and vegetation is basic to studies of watershed management and serves as a guide in designing remedial programs suited to the needs and limitations of the resource. After the interrelationship of these factors is understood, interpretations regarding land use and management can be made. These include land capability classification for cropland, range, forest, and woodland production and the determination of suitability for road location, recreation, and building sites.

AVAILABLE DATA

Aerial photographs of the entire North Coastal Survey Area were taken in 1965 for this study and were used in combination with available older photographs. The oldest, taken in 1941, cover most of Mendocino County; 1944, 1948, and 1952 photographs cover the remainder of the basins.

The Ukiah, Redding, and Weed Sheets of the "Geologic Map of California" published by the California Division of Mines and Geology[1-3] were used to develop a generalized geologic map.

This reconnaissance survey used available data and maps. The Soil-Vegetation Maps funded by the California Division of Forestry and prepared by the Pacific Southwest Forest and Range Experiment Station [4], cover the upland area outside the national forests and portions of the Mendocino National Forest in Glenn and Lake Counties, but they were not available for the rest of the national forest land.

1/ California Resources Agency, Department of Conservation, Division of Mines and Geology, "Geologic Map of California; Ukiah Sheet." (San Francisco, 1960).

2/ "Geologic Map of California; Redding Sheet." (1962).

3/ "Geologic Map of California; Weed Sheet." (1964).

4/ Cooperative Soil-Vegetation Survey Project: California Department of Natural Resources, Division of Forestry, in cooperation with the University of California and the USDA Forest Service, California Forest and Range Experiment Station. "Upland Soils /Map/ of Glenn County." (Sacramento; State Printing Division, Documents Section, 1957).

"Upland Soils /Map/ of Lake County," (1955).

"Upland Soils /Map/ of Mendocino County," (1951).

"Soil Vegetation Survey Maps." (San Francisco, USDA Forest Service, latest available editions).

The survey team prepared generalized soil association maps for the unmapped portions with the help of Forest Service Soil Scientists. Information from several published and unpublished reports[1-3], was used in preparing the maps. The most recent editions of U. S. Geologic Survey Topographic Quadrangles[4] were used to determine slope gradients where they were not shown on the Soil-Vegetation Maps.

The Vegetal Cover Types Maps for the Eel River Basin were prepared from the Soil-Vegetation Maps when they were available. For areas not covered by Soil-Vegetation Maps, they were developed from Timber Stands Maps[5] and Range Management Maps[5]. For the Mad River Basin, they were made from Timber Stand Maps. Information from the maps was supplemented with vegetal cover interpretations made from 1965 aerial photographs of those areas where commercial species are not present.

1/ Robert A. Gardner and others, Wildland Soils and Associated Vegetation of Mendocino County, California. (Sacramento; Resources Agency of California, Cooperative Soil-Vegetation Survey Project, 1964). 113 pp.

2/ James McLaughlin and Frank Harradine, Soils of Western Humboldt County, California. (Davis; Department of Soils and Plant Nutrition, University of California, Davis, in cooperation with the County of Humboldt, November 1965.) 85 pp.

3/ USDA Soil Conservation Service, "Report and General Soil Map, Humboldt County, California." (Unpublished report, April 1967). 51 pp.

"Report and General Soil Map, Mendocino County, California." (Unpublished report, February 1967). 56 pp.

4/ USDI Geologic Survey, Topographic Quadrangles. (Washington, D.C., USGS, latest available editions).

5/ USDA Forest Service, "Timber Stands Maps." (San Francisco, latest available editions).

"Range Management Maps." (San Francisco, latest available editions).

TOPOGRAPHY

The principal topographical features of the Eel and Mad River Basins are the rugged northwest-southeast trending ridges and canyons. Maximum elevations are found along the eastern boundary and range from about 4,500 to 7,500 feet. Black Butte, Anthony Peak, and Sheet Iron Mountain are prominent mountains with elevations of more than 6,500 feet. Although the North Fork, Middle Fork, and main stem of the Eel River flow south to southeast in their upper reaches, they eventually cross the structural grain of the basin and join in a northwest course toward the Pacific Ocean. Many of the smaller tributaries start out in a similar manner. The resulting trellis drainage pattern reflects the marked geologic control of the stream courses.

The coastal areas are characterized by nearly flat alluvial valleys and tidal plains with small areas of sand dunes. The Eel River has developed a broad flood plain above its entrance to the Pacific Ocean. The Mad and Van Duzen Rivers and Redwood Creek, which drain into the ocean or onto the Eel Delta, have developed smaller flood plains. Gently sloping terraces ranging from 100 to 700 feet in elevation are found a few miles inland from the coast. Three relatively flat valleys (Laytonville, Willits, and Round Valley) are located in the mountainous part of the basins.

There are no large natural lakes in the basins. Howard, Hammerhorn, and Keller Lakes are among several small lakes comprising a few acres or less. Some of these lakes are slump ponds formed by landslides; others are man-made impoundments.

GEOLOGY

Geologically, California is extremely varied and complex. For this reason, it is convenient to discuss the geology of various parts of the state in terms of geomorphic provinces. Within its borders the state has all or parts of 11 provinces, each characterized by similar land forms and geology, with distinctive mineral deposits and sediment yields.

The Coast Ranges province, which includes the Eel and Mad River Basins, extends from near Santa Barbara to the Oregon border and from the Central Valley to the Pacific Ocean. The highest sediment yields for streams of comparable size in the province, and for that matter, in the State are produced by streams draining the Coast Ranges north of San Francisco Bay. The Eel River has the highest average annual sediment yield per square mile and also has the highest reported yield per square mile of any stream of comparable size in the United States.1/

1/ Sheldon Judson and Dale F. Ritter, "Rates of Regional Denudation in the U. S." Jour. Geophysical Research, vol. 69, No. 16, pp. 3395-3401 (1964).

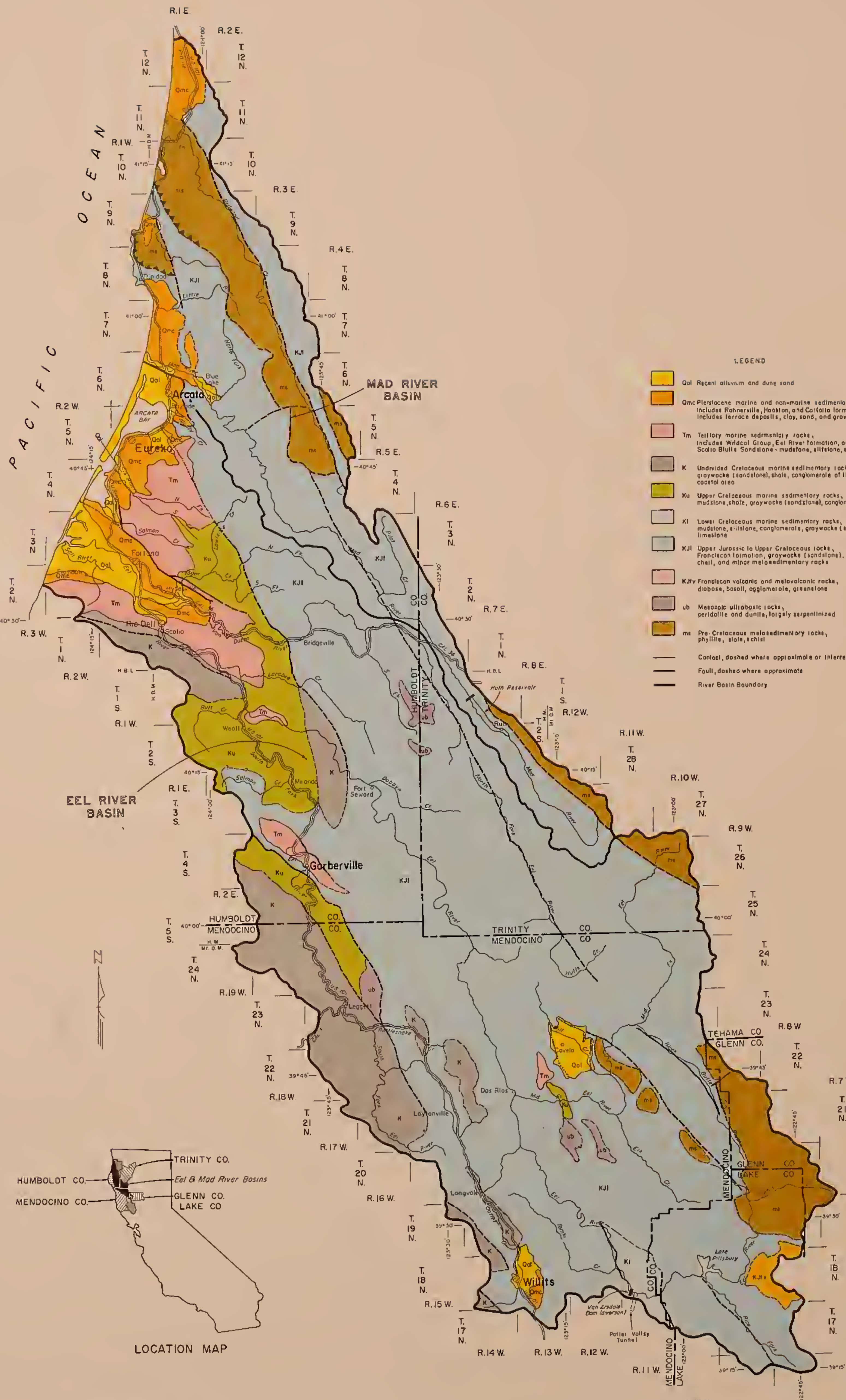
The basins contain rocks typical of those found in the northern part of the Coast Ranges province. The rocks range in age from Late Jurassic to Recent and are predominantly marine sediments. About 80 percent of the area is underlain by the Franciscan formation and the rocks generally associated with it. The Great Valley sequence comprises about 7 percent, and Tertiary rocks comprise about 5 percent of the area. The remaining 8 percent is underlain by alluvium and terrace deposits. The extent of these geologic assemblages is shown on the Generalized Geologic Map on the following page and in the table below:

	Area (Square Miles)			
	Eel River Basin	Mad River Basin	Total	Percent
Franciscan formation	3,046	832	3,878	80.2
Great Valley sequence	339	-	339	7.0
Tertiary formations	207	11	218	4.5
Alluvium and terrace deposits	313	86	399	8.3
Totals	3,905	929	4,834	100

The Franciscan formation is a heterogeneous mass of sedimentary, volcanic, and metamorphic rocks deformed by folds, faults, and metamorphism. The formation has been intruded by basic and ultrabasic rocks that are predominantly serpentinized, and the volcanic rocks are interbedded with the marine sediments. These volcanic rocks are mostly submarine lava flows that are now largely altered to greenstone. By far the most prevalent rock type in the Franciscan formation is greywacke, a sandstone, which is commonly associated with minor amounts of shale. The Great Valley sequence, although about the same age as the Franciscan formation, has less volcanic rock and chert and many more fossils; it is also much less structurally deformed and much more regularly bedded.

Tertiary rocks crop out in extensive areas south and west of Round Valley in the Middle Fork Subbasin and in small isolated areas around Eureka and the Eel River Delta. Generally, the Tertiary rocks are of marine origin and consist of sandstone, siltstone, and conglomerate. Rocks of younger age also appear in isolated deposits; the most extensive of these occur along the coast from the mouth of the Eel River to Redwood Creek.

Erodibility of the various broad geologic formations or assemblages is variable and depends upon many factors, such as mineralogy, degree of weathering, and structural history. Generally, the Franciscan formation, which includes about 80 percent of the rocks mapped in the basins, is highly unstable, largely because of the presence of both small and very large faults and shear zones often hundreds of feet wide. The deeply weathered Franciscan formation contains shale interbedded with more massive rocks, and serpentinite is common. These inherently weak structural features, combined with high rainfall, intense storms, high peak flows, and rugged topography, account for the widespread slope instability and erodibility of the Franciscan formation. Consequently, landslides, streambank erosion, and soil creep are prevalent and are the major modes of degradation of the landscape in the Eel and Mad River Basins.



GENERALIZED GEOLOGIC MAP
EEL & MAD RIVER BASINS
GLENN, HUMBOLDT, LAKE, MENDOCINO & TRINITY COUNTIES, CALIFORNIA

JUNE 1968

0 5 10 MILES
SCALE 1 : 760,320

SOILS

Information from published soil surveys was utilized and supplemented by a generalized soil map of national forest land, prepared for this study.

Several hundred phases of about 80 soil series and miscellaneous land types were combined into 40 soil associations. Soil association names were derived from soil series names. The distribution of the soil associations and slope groups is shown on the following pages on the General Soil Map and in the table "Approximate Areas of Soil Associations."

The accompanying table "Soil Characteristics, Qualities, and Interpretive Groupings" shows the main components of the soil associations and some soil features. An estimate of areal proportion of the major soils and of the other soils included in each association is shown in percentages. Terms used in describing soil texture, reaction, substratum or parent material, drainage class, and subsoil permeability are in accordance with the Soil Survey Manual, USDA Handbook No. 18 (Washington, U. S. Government Printing Office, August 1951. 503 pp.) Of the 40 soil associations, numbers 8,9, 17,24,25,29,34,37 and 39 were used in data analysis but are small in area and are not shown as separate units on the General Soil Map or in the tables in this report. The soil areas delineated on the General Soil Map show the most prevalent soil association.

Likewise, the classifications of the most prevalent soil components are delineated on the other maps in this appendix. For example, soils in the Sheetiron-Hugo association (30 - 75 percent slopes) are delineated as Group C rather than Group B on the Hydrologic Soil Groups Map because Sheetiron soils (classified as Group C) comprise 50 percent of the association.

The Land Capability Classification[1/] is a grouping of soils made primarily for agricultural purposes, but is not designed for definitive classification of timber and range production potentials. Soils and climate are considered together as they influence use, management, and production.

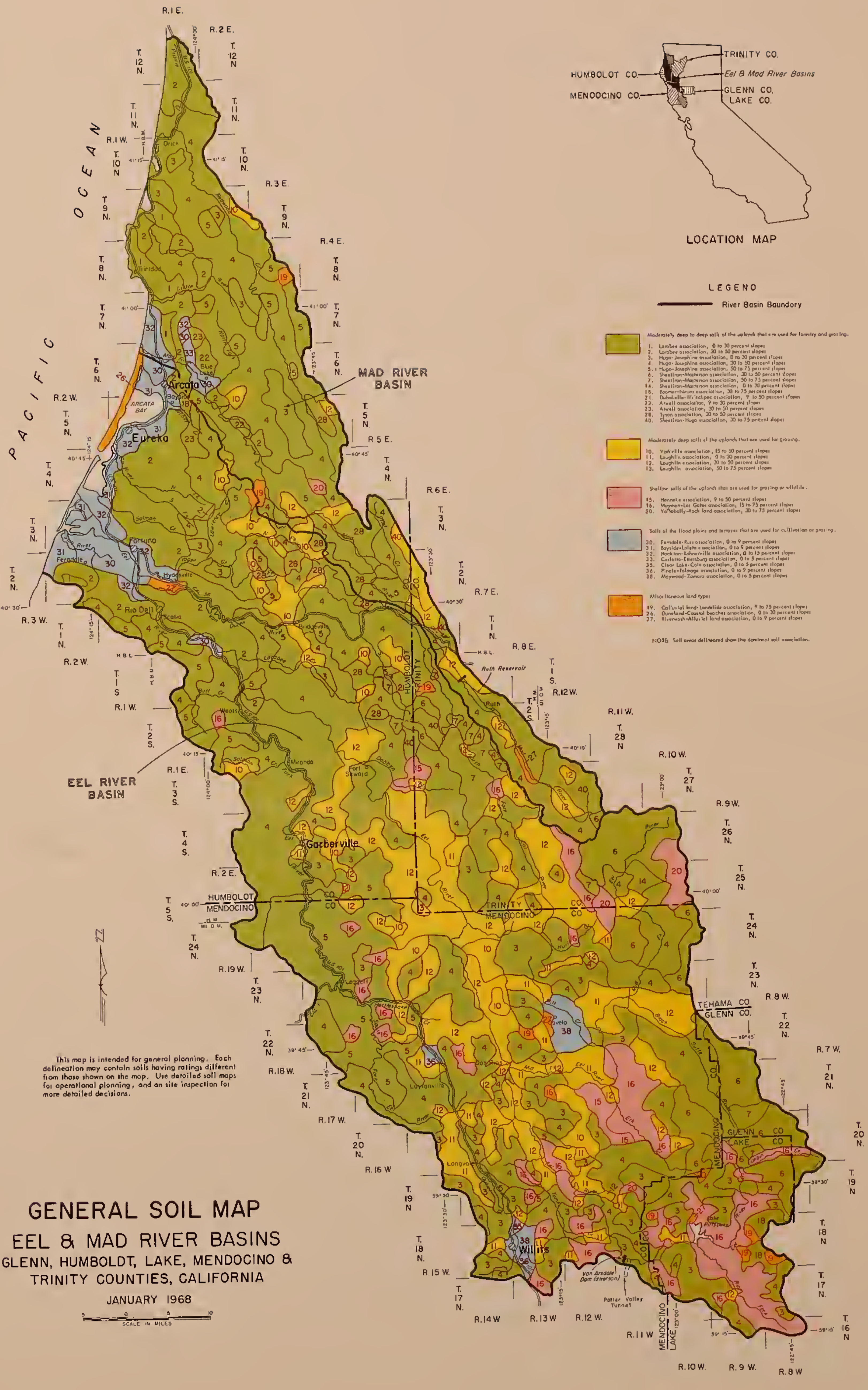
The classification contains two general divisions: (1) land suited for cultivation and other uses; and (2) land limited in use and generally not suited for cultivation. Each of these broad divisions has four classes, each designated by a roman numeral that reflects increasing hazards and limitations in land use. Class I has few or no hazards or limitations in agricultural use, whereas Class VIII has many. The classes are described on the following pages.

Capability classes are divided into subclasses that reflect the principal kinds of limitations: "e" for erosion, "w" for wetness, "s" for soil, and "c" for climate.

1/ USDA Soil Conservation Service, Land-Capability Classification, Agriculture Handbook No. 210. (Washington, U. S. Government Printing Office, September 1961). 21 pp.

Approximate Area of Soil Associations

Soil Assn. (No.)	Soil Associations (Name)	Area (Square Miles)	
		Eel River Basin	Mad River Basin
1.	Larabee association, 0 to 30% slopes	10	40
2.	Larabee association, 30 to 50% slopes	200	70
3.	Hugo-Josephine association, 0 to 30% slopes	305	45
4.	Hugo-Josephine association, 30 to 50% slopes	1,165	410
5.	Hugo-Josephine association, 50 to 75% slopes	355	105
6.	Sheetiron-Masterson association, 30 to 50% slopes	220	5
7.	Sheetiron-Masterson association, 50 to 75% slopes	75	-
10.	Yorkville association, 15 to 50% slopes	160	25
11.	Laughlin association, 0 to 30% slopes	160	-
12.	Laughlin association, 30 to 50% slopes	420	45
13.	Laughlin association, 50 to 75% slopes	15	-
14.	Sheetiron-Masterson association, 0 to 30% slopes	15	-
15.	Henneke association, 9 to 50% slopes	25	-
16.	Maymen-Los Gatos association, 15 to 75% slopes	270	5
18.	Boomer-Neuns association, 30 to 75% slopes	15	-
19.	Colluvial land-Landslide association, 9 to 75% slopes	65	5
20.	Yollabolly-Rock land association, 30 to 75% slopes	60	10
21.	Dubakella-Weitchpec association, 9 to 50% slopes	10	-
22.	Atwell association, 9 to 30% slopes	-	15
23.	Atwell association, 30 to 50% slopes	15	5
26.	Dune land-Coastal beaches association, 0 to 30% slopes	15	5
27.	Riverwash-Alluvial land association, 0 to 9% slopes	35	4
28.	Tyson association, 30 to 50% slopes	40	65
30.	Ferndale-Russ association, 0 to 9% slopes	70	15
31.	Bayside-Loleta association, 0 to 9% slopes	50	5
32.	Hookton-Rohnerville association, 0 to 15% slopes	40	15
33.	Carlotta-Ettersburg association, 0 to 5% slopes	10	5
35.	Clear Lake-Cole association, 0 to 5% slopes	10	-
36.	Pinole-Talmage association, 0 to 9% slopes	20	-
38.	Maywood-Zamora association, 0 to 5% slopes	35	-
40.	Sheetiron-Hugo association, 30 to 75% slopes	20	30
	Totals	3,905	929



This map is intended for general planning. Each delineation may contain soils having ratings different from those shown on the map. Use detailed soil maps for operational planning, and an site inspection for more detailed decisions.

GENERAL SOIL MAP

EEL & MAD RIVER BASINS

GLENN, HUMBOLDT, LAKE, MENDOCINO & TRINITY COUNTIES, CALIFORNIA

JANUARY 1968

U S DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

M7-S-20669-N

SOIL CHARACTERISTICS, QUALITIES, AND INTERPRETIVE GROUPINGS
EEL AND MAD RIVER BASINS

SOIL MAP SYMBOL	SOIL ASSOCIATIONS AND MAJOR COMPONENTS	PERCENT[1] OF ASSOCIATION	LAND CAPABILITY SUBCLASS		LAND RESOURCE AREA	SOIL PROFILE					DRAINAGE CLASS	SUBSOIL PERMEABILITY	EROSION HAZARD	EFFECTIVE DEPTH (INCHES)	AVAILABLE WATER CAPACITY (INCHES)	HYDROLOGIC SOIL GROUP	UNIFIED SOIL CLASS. (SUBSOIL)
						SURFACE LAYER		SUBSOIL		SUBSTRATUM OR PARENT MATERIAL							
			IRRIGATED	DRY		TEXTURE	REACTION(pH)	TEXTURE	REACTION(pH)								
1	Larabec association, 0 to 30 percent slopes																
	Larabee	90 (10)		VIe	4	Loam	Slightly acid	Clay loam	Strongly acid	Soft sedimentary rocks	Well	Moderate or moderately slow	Moderate	36 to 60+	5 to 11	B	CL
2	Larabee association, 30 to 50 percent slopes																
	Larabee	90 (10)		VIIe	4	Loam	Slightly acid	Clay loam	Strongly acid	Soft sedimentary rocks	Well	Moderate or moderately slow	High	36 to 60+	5 to 11	B	CL
3	Hugo - Josephine association, 0 to 30 percent slopes																
	Hugo	60	IVe		4, 5, 15	Loam	Medium acid	Loam	Strongly acid	Sandstone (Graywacke)	Well	Moderate	Moderate	30 to 60	4 to 11	B	ML, CL
	Josephine	25 (15)	IVe		4, 5, 15	Loam	Medium acid	Clay loam	Strongly acid	Sandstone (Graywacke)	Well	Moderate or moderately slow	Moderate	30 to 60+	4 to 11	B	CL, SM, ML
4	Hugo - Josephine association, 30 to 50 percent slopes																
	Hugo	65		VIe	4, 5, 15	Loam	Medium acid	Loam	Strongly acid	Sandstone (Graywacke)	Well	Moderate	High	30 to 60	4 to 11	B	ML, CL
	Josephine	20 (15)		VIe	4, 5, 15	Loam	Medium acid	Clay loam	Strongly acid	Sandstone (Graywacke)	Well	Moderate or moderately slow	High	30 to 60+	4 to 11	B	CL, SM, ML
5	Hugo - Josephine association, 50 to 75 percent slopes																
	Hugo	75		VIIe	4, 5, 15	Loam	Medium acid	Loam	Strongly acid	Sandstone (Graywacke)	Well	Moderate	Very high	30 to 60	4 to 11	B	ML, CL
	Josephine	10 (15)		VIIe	4	Loam	Medium acid	Clay loam	Strongly acid	Sandstone (Graywacke)	Well	Moderate or moderately slow	Very high	30 to 60+	4 to 11	B	CL, SM, ML
6	Sheetiron - Masterson association, 30 to 50 percent slopes																
	Sheetiron	60		VIIe	5	Gravelly loam	Medium acid	Gravelly loam	Strongly acid	Metamorphosed sedimentary rocks	Somewhat excessively	Moderate	High	20 to 40	2 to 6	C[2]	GM, GC
	Masterson	20 (20)		VIIs	5	Gravelly loam	Strongly acid	Gravelly loam	Strongly acid	Metamorphosed sedimentary rocks	Well	Moderately rapid	High	20 to 40	2 to 6	B	GM, GC
7	Sheetiron - Masterson association, 50 to 75 percent slopes																
	Sheetiron	60		VIIe	5	Gravelly loam	Medium acid	Gravelly loam	Strongly acid	Metamorphosed sedimentary rocks	Somewhat excessively	Moderate	Very high	20 to 40	2 to 6	C[2]	GM, GC
	Masterson	20 (20)		VIIs	5	Gravelly loam	Strongly acid	Gravelly loam	Strongly acid	Metamorphosed sedimentary rocks	Well	Moderately rapid	Very high	20 to 40	2 to 6	B	GM, GC
10	Yorkville association, 15 to 50 percent slopes																
	Yorkville	75 (25)		VIe	15, 4, 5	Clay loam	Neutral	Clay	Mildly alkaline	Metamorphosed basic rocks	Moderately well or somewhat poorly	Slow	Very high	20 to 40	4 to 9	D	CH

1/ PERCENT IN (___) GIVES EXTENT OF OTHER SOILS IN THE ASSOCIATIONS.
2/ INDICATES RATING USED ON HYDROLOGIC SOIL GROUPS MAP.

SOIL CHARACTERISTICS, QUALITIES, AND INTERPRETIVE GROUPINGS
EEL AND MAD RIVER BASINS

SOIL MAP SYMBOL	SOIL ASSOCIATIONS AND MAJOR COMPONENTS	PERCENT[1] OF ASSOCIATION	LAND CAPABILITY SUBCLASS		LAND RESOURCE AREA	SOIL PROFILE					DRAINAGE CLASS	SUBSOIL PERMEABILITY	EROSION HAZARD	EFFECTIVE DEPTH (INCHES)	AVAILABLE WATER CAPACITY (INCHES)	HYDROLOGIC SOIL GROUP	UNIFIED SOIL CLASS. (SUBSOIL)
						SURFACE LAYER		SUBSOIL		SUBSTRATUM OR PARENT MATERIAL							
			IRRIGATED	DRY		TEXTURE	REACTION(pH)	TEXTURE	REACTION(pH)								
11	Laughlin association, 0 to 30 percent slopes																
	Laughlin	80 (20)	IVe		5, 15	Loam	Medium acid	Loam	Medium acid	Sandstone (Graywacke)	Well	Moderately rapid	Moderate	20 to 40	2 to 5	B	ML
12	Laughlin association, 30 to 50 percent slopes																
	Laughlin	80 (20)		VIe	5, 15	Loam	Medium acid	Loam	Medium acid	Sandstone (Graywacke)	Well	Moderately rapid	High	20 to 40	2 to 5	B	ML
13	Laughlin association, 50 to 75 percent slopes																
	Laughlin	80 (20)		VIIe	5, 15	Loam	Medium acid	Loam	Medium acid	Sandstone (Graywacke)	Well	Moderately rapid	Very high	20 to 40	2 to 5	B	ML
14	Sheetiron - Masterson association, 0 to 30 percent slopes																
	Sheetiron	60		VIe	5	Gravelly loam	Medium acid	Gravelly loam	Strongly acid	Metamorphosed sedimentary rocks	Somewhat excessively	Moderate	Moderate	20 to 40	2 to 6	C 2/	GM,GC
	Masterson	20 (20)		VIs	5	Gravelly loam	Strongly acid	Gravelly loam	Strongly acid	Metamorphosed sedimentary rocks	Well	Moderately rapid	Moderate	20 to 40	2 to 6	B	GM,GC
15	Henneke association, 9 to 50 percent slopes																
	Henneke	85 (15)		VIIs	15	Very gravelly loam	Slightly acid	Very gravelly clay loam	Neutral	Serpentine	Well	Moderately slow	High	5 to 20	1 to 3	D	GM, SC,GC
16	Maymen - Los Gatos association, 15 to 75 percent slopes																
	Maymen	50		VIIIs 2/	15, 5	Gravelly loam	Medium acid	Gravelly loam	Strongly acid	Sandstone (Graywacke)	Somewhat excessively	Moderately rapid	Very high	5 to 20	1 to 3	D 2/	SM
	Los Gatos	30 (20)		VIIe	15, 5	Gravelly loam	Slightly acid	Gravelly clay loam	Medium acid	Sandstone (Graywacke)	Well	Moderately slow	Very high	16 to 30	2 to 5	C	SC,CL
18	Boomer - Neuns association, 30 to 75 percent slopes																
	Boomer	75		VIIe	5	Gravelly loam	Medium acid	Gravelly clay loam	Medium acid	Metamorphosed basic igneous rocks	Well	Moderately slow	Very high	30 to 60	3 to 9	B	SC,SM, GC,GM
	Neuns	20 (5)		VIIs	5	Gravelly sandy loam	Medium acid	Very gravelly clay loam	Medium acid	Metamorphosed basic igneous rocks	Somewhat excessively	Moderate	Very high	24 to 48	3 to 7	B	GM,GC
19	Colluvial land - Landslide association, 9 to 75 percent slopes																
	Colluvial land	60		VIIIs	—	Mixed deposits of soil materials and rock fragments					—	—	Very high	—	—	—	—
	Landslide	30 (10)		VIIIe	—	Mixed deposits of soil materials and rock fragments and exposed surfaces resulting from loss of material					—	—	Very high	—	—	—	—

1/ PERCENT IN (___) GIVES EXTENT OF OTHER SOILS IN THE ASSOCIATIONS.

2/ INDICATES RATING USED ON GENERAL LAND CAPABILITY OR HYDROLOGIC SOIL GROUPS MAPS.

SOIL CHARACTERISTICS, QUALITIES, AND INTERPRETIVE GROUPINGS
EEL AND MAD RIVER BASINS

SOIL MAP SYMBOL	SOIL ASSOCIATIONS AND MAJOR COMPONENTS	PERCENT[1] OF ASSOCIATION	LAND CAPABILITY SUBCLASS		LAND RESOURCE AREA	SOIL PROFILE					DRAINAGE CLASS	SUBSOIL PERMEABILITY	EROSION HAZARD	EFFECTIVE DEPTH (INCHES)	AVAILABLE WATER CAPACITY (INCHES)	HYDROLOGIC SOIL GROUP	UNIFIED SOIL CLASS. (SUBSOIL)
						SURFACE LAYER		SUBSOIL		SUBSTRATUM OR PARENT MATERIAL							
			IRRIGATED	DRY		TEXTURE	REACTION (pH)	TEXTURE	REACTION (pH)								
20	Yollabolly - Rock land association, 30 to 75 percent slopes																
	Yollabolly	60		VIIs	5	Gravelly loam	Strongly acid	Stony very gravelly loam	Strongly acid	Metamorphosed sedimentary rocks	Excessively	Rapid	Very high	5 to 20	1 to 3	D	GM,GC
	Rock land	25 (15)		VIIIs	—	Very shallow soil materials and rock outcrops					—	—	—	—	—	—	—
21	Dubakella - Weitchpec association, 9 to 50 percent slopes																
	Dubakella	80		VIs[2]	5	Stony loam	Neutral	Gravelly loam	Mildly alkaline	Serpentine	Well	Moderate	High	20 to 40	2 to 4	C[2]	GM,GC
	Weitchpec	10 (10)		VIe	5	Very gravelly loam	Medium acid	Stony gravelly loam	Slightly acid	Serpentine and peridotite	Well to excessively	Rapid	High	20 to 40	3 to 5	B	GM,GC
22	Atwell association, 9 to 30 percent slopes																
	Atwell	90 (10)	IVe		4	Clay loam	Strongly acid	Clay	Strongly acid	Clay and soft sedimentary rocks	Moderately well	Slow	High	36 to 60	6 to 9	C	CL,CH
23	Atwell association, 30 to 50 percent slopes																
	Atwell	90 (10)		VIe	4	Clay loam	Strongly acid	Clay	Strongly acid	Clay and soft sedimentary rocks	Moderately well	Slow	High	36 to 60	6 to 9	C	CL,CH
26	Dune land - Coastal beaches association, 0 to 30 percent slopes																
	Dune land	45		VIIIe[2]	4	Coastal sand dunes consisting of medium and coarse sand					Excessively	Very rapid	Moderate	60+	2 to 3	A[2]	SW,SP
	Coastal beaches	45 (10)		VIIIw	4	Sandy and rocky beaches subject to frequent wave action					—	—	—	—	—	—	—
27	Riverwash - Alluvial land association, 0 to 9 percent slopes																
	Riverwash	55		VIIIw[2]	—	Sandy, gravelly, and cobbly materials along stream channels					—	—	Very high	—	—	A	GP,GW, SP,SW
	Alluvial land	30 (15)		VIIw	—	Alluvial deposits varying widely in texture and subject to frequent changes through stream overflow					—	—	Very high	10 to 60	—	A	—
28	Tyson association, 30 to 50 percent slopes																
	Tyson	85 (15)		VIIs	5	Gravelly loam	Slightly acid	Very gravelly clay loam	Medium acid	Sandstone (Graywacke)	Well	Moderate	Very high	20 to 48	2 to 4	C	GC
30	Ferndale - Russ association, 0 to 9 percent slopes																
	Ferndale	60	IIw		4	Silt loam	Neutral	Silt loam	Neutral	Stratified sand, loam and gravel	Well	Moderate	Low	60+	10 to 12	B	ML
	Russ	15 (25)	IIw		4	Loam	Slightly acid	Loam	Medium acid	Loam	Moderately well or somewhat poorly	Moderate or moderately slow	Low	60+	10 to 12	B	ML

1/ PERCENT IN (___) GIVES EXTENT OF OTHER SOILS IN THE ASSOCIATIONS.

2/ INDICATES RATING USED ON GENERAL LAND CAPABILITY OR HYDROLOGIC SOIL GROUPS MAPS.

SOIL CHARACTERISTICS, QUALITIES, AND INTERPRETIVE GROUPINGS
EEL AND MAD RIVER BASINS

SOIL MAP SYMBOL	SOIL ASSOCIATIONS AND MAJOR COMPONENTS	PERCENT OF ASSOCIATION 1/	LAND CAPABILITY SUBCLASS		LAND RESOURCE AREA	SOIL PROFILE					DRAINAGE CLASS	SUBSOIL PERMEABILITY	EROSION HAZARD	EFFECTIVE DEPTH (INCHES)	AVAILABLE WATER CAPACITY (INCHES)	HYDROLOGIC SOIL GROUP	UNIFIED SOIL CLASS. (SUBSOIL)
			IRRIGATED	DRY		SURFACE LAYER TEXTURE	SURFACE LAYER REACTION (pH)	SUBSOIL TEXTURE	SUBSOIL REACTION (pH)	SUBSTRATUM OR PARENT MATERIAL							
31	Bayside - Loleta association, 0 to 9 percent slopes																
	Bayside	50	IVw 2/		4	Silty clay loam	Slightly acid	Clay	Mildly alkaline	Stratified loam and clay loam	Poorly	Moderately slow or slow	Low	20 to 40	4 to 7	D 2/	CH
	Loleta	30 (20)	IIIw		4	Loam	Medium acid	Loam	Medium acid	Stratified loams and sands	Moderately well or somewhat poorly	Slow	Low	48 to 60	9 to 11	C	ML
32	Hookton - Rohnerville association, 0 to 15 percent slopes																
	Hookton	50	IVe 2/		4	Silty clay loam	Medium acid	Silty clay loam	Strongly acid	Conglomerate, clay, sand, mudstone	Moderately well	Moderate or moderately slow	Moderate	20 to 40	4 to 10	C 2/	ML,CL
	Rohnerville	20 (30)	IIIe		14	Silty clay loam	Medium acid	Silty clay loam	Medium acid	Conglomerate, clay, sand, mudstone	Well or moderately well	Moderate or moderately slow	Moderate	40 to 60	6 to 11	B	ML,CL, CH
33	Carlotta - Ettersburg association, 0 to 5 percent slopes																
	Carlotta	35	IIe		4	Loam	Slightly acid	Loam	Strongly acid	Stratified loam and gravel	Moderately well	Moderate or moderately slow	Low	40 to 60	6 to 11	B	ML
	Ettersburg	35 (30)	IIe		4	Loam	Very strongly acid	Loam	Very strongly acid	Gravel	Well	Moderate	Low	40 to 60	6 to 10	B	ML
35	Clear Lake - Cole association, 0 to 5 percent slopes																
	Clear Lake	45	IIIw 2/		14	Clay	Slightly acid	Clay	Moderately alkaline	Clay	Poorly	Slow or very slow	Low	60	8 to 10	D 2/	CH
	Cole	45 (10)	IIw		14	Loam	Medium acid	Sandy clay	Medium acid	Sandy clay	Somewhat poorly	Moderate to slow	Low	60	7 to 9	C	CL,CH
36	Pinole - Talmage association, 0 to 9 percent slopes																
	Pinole	55	IIe 2/		14	Gravelly loam	Strongly acid	Clay loam	Medium acid	Very gravelly sandy loam	Well	Moderate or moderately rapid	Low	40 to 60	5 to 10	B 2/	ML
	Talmage	25 (20)	IIIs		14	Gravelly sandy loam	Slightly acid	Very gravelly sandy loam	Slightly acid	Gravelly coarse loamy sand	Somewhat excessively	Rapid	Low	20 to 40	3 to 4	A	GM
38	Maywood - Zamora association, 0 to 5 percent slopes																
	Maywood	55	IIw 2/		4	Very fine sandy loam	Medium acid	Very fine sandy loam	Medium acid	Silt loam	Well	Moderately rapid	Low	60+	8 to 12	B	SM
	Zamora	30 (15)	IIe		14	Silt loam	Medium acid	Silt loam	Slightly acid	Silty clay loam	Well or moderately well	Moderate or moderately slow	Low	60+	7 to 11	B	ML
40	Sheetiron - Hugo association, 30 to 75 percent slopes																
	Sheetiron	50		VIIe	5	Gravelly loam	Medium acid	Gravelly loam	Strongly acid	Metamorphosed sedimentary rocks	Somewhat excessively	Moderate	Very high	20 to 40	2 to 6	C2/	GM,GC
	Hugo	40 (10)		VIIe	5	Loam	Medium acid	Loam	Strongly acid	Sandstone (Greywacke)	Well	Moderate	Very high	30 to 60	4 to 11	B	ML,CL

1/ PERCENT IN (___) GIVES EXTENT OF OTHER SOILS IN THE ASSOCIATIONS.

2/ INDICATES RATING USED ON GENERAL LAND CAPABILITY OR HYDROLOGIC SOIL GROUPS MAPS.

Land Capability Classification

Land Suited for Cultivation and Other Uses

Class I	Soils in Class I have few or no limitations or hazards. They may be used safely for cultivated crops, pasture, grazing, production of forest products, recreation, or wildlife.
Class II	Soils in Class II have few limitations or hazards. Simple conservation practices are needed when cultivated. They are suited to cultivated crops, pasture, grazing, production of forest products, recreation, or wildlife.
Class III	Soils in Class III have more limitations and hazards than those in Class II and require more difficult or complex conservation practices when cultivated. They are suited to crops, pasture, grazing, production of forest products, recreation, or wildlife.
Class IV	Soils in Class IV have greater limitations and hazards than Class III, and still more difficult or complex measures are needed when cultivated. They are suited to cultivated crops, pasture, grazing, production of forest products, recreation, or wildlife.

Land Limited in Use; Generally not Suited for Cultivation

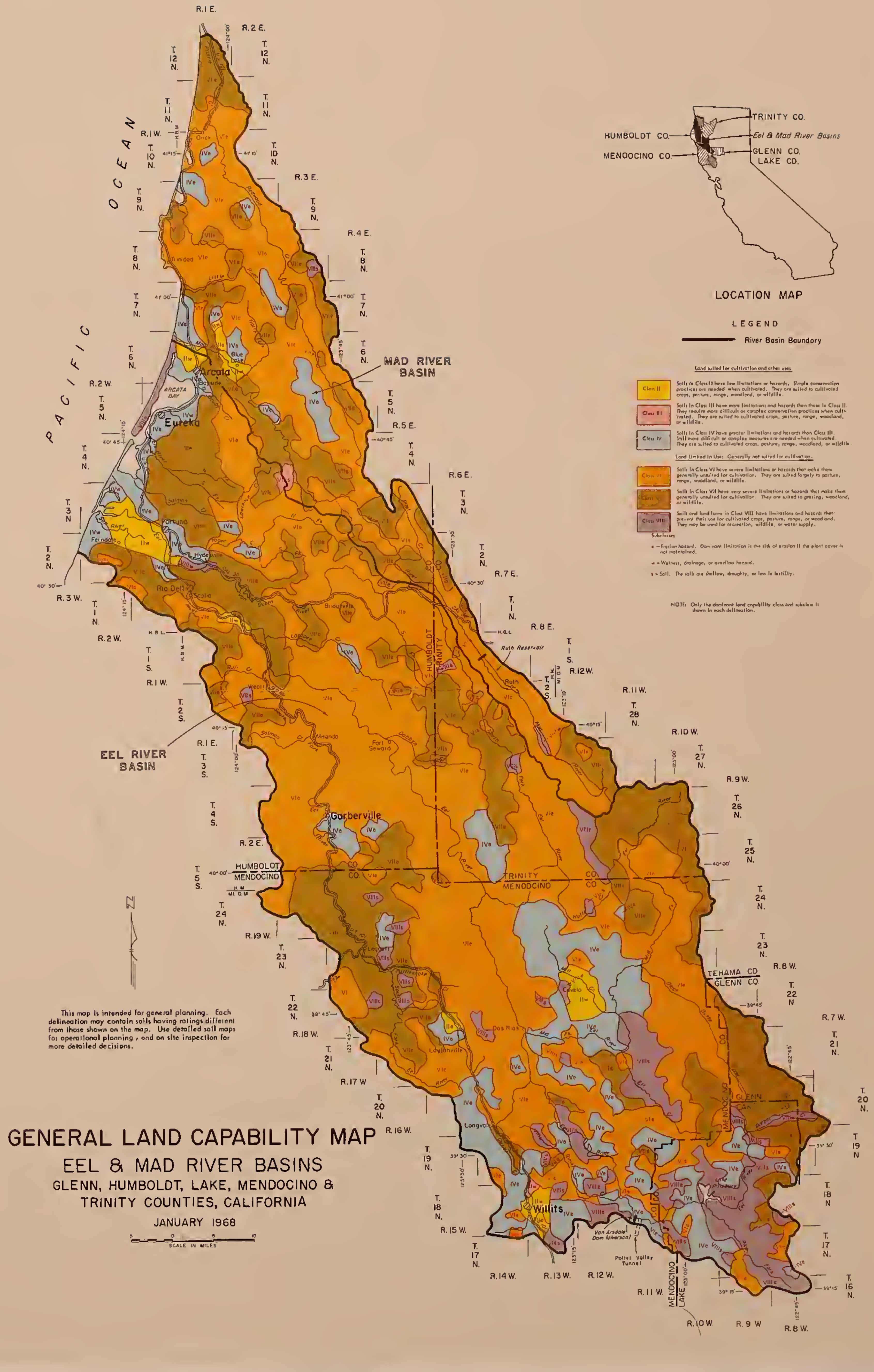
Class V	Soils in Class V have little or no erosion hazard but have other limitations that prevent normal tillage for cultivated crops. They are suited to pasture, production of forest products, grazing, recreation, or wildlife.
Class VI	Soils in Class VI have severe limitations or hazards that make them generally unsuited for cultivation. They are suited largely to pasture, grazing, production of forest products, recreation, or wildlife.
Class VII	Soils in Class VII have very severe limitations or hazards that make them generally unsuited for cultivation. They are suited to grazing, production of forest products, recreation, or wildlife.
Class VIII	Soils and land forms in Class VIII have limitations and hazards that prevent their use for cultivated crops, pasture, grazing, or the production of forest products. They may be used for recreation, wildlife, or water supply.

The distribution of classes and subclasses is shown in the following table and on the General Land Capability Map.

Land Capability Class and Subclass	Area (Square Miles) Eel Basin	Mad Basin	Total	Percent of Total Area
II e	25	5	30	0.6
II w	110	15	125	2.6
III e	15	5	20	0.4
III w	25	-	25	0.5
IV e	495	75	570	11.8
IV w	30	5	35	0.7
VI e	1,785	515	2,300	47.7
VI s	10	10	20	0.4
VII e	1,050	275	1,325	27.4
VII s	65	5	70	1.4
VII w	10	-	10	0.2
VIII e	10	5	15	0.3
VIII s	245	10	255	5.3
VIII w	30	4	34	0.7
Total	3,905	929	4,834	100.0

Land Resource Areas are geographic divisions that have particular patterns of soil, climate, water resources, topography, and land use. There are portions of four major Land Resource Areas in the basins: LRA 4 -- the California Coastal Redwood Belt; LRA 5 -- the Siskiyou-Trinity Area; LRA 14 -- the Central California Coastal Valleys; and LRA 15 -- the Central California Coast Range. These comprise, respectively, 38, 36, 1, and 25 percent of the study area.

Erosion hazard describes the susceptibility of the soil to erosion by water or wind under specified conditions. In general, the risk of erosion depends upon the land slope, the texture and structure of the soil, the type and amount of vegetal cover, and the amount of runoff; slope is a dominant factor. In this report the erosion hazard is an estimate of the degree of water erosion to be expected if all of the protective vegetal cover is removed. The classes used in rating water erosion hazard for bare soil are determined by the following slope intervals:



GENERAL LAND CAPABILITY MAP
EEL & MAD RIVER BASINS
GLENN, HUMBOLDT, LAKE, MENDOCINO & TRINITY COUNTIES, CALIFORNIA
JANUARY 1968

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

M7-S-20697-N

Erosion Hazard Class (rating)	Slope Interval (percent)
Low	0 to 9
Moderate	9 to 30
High	30 to 50
Very High	Over 50

The distribution of the erosion hazard classes is as follows:

Erosion Hazard Class (rating)		Area (Square Miles)	
		Eel Basin	Mad Basin
Low		195	25
Moderate		545	105
High		2,055	550
Very High		1,110	249
	Total	3,905	929

Effective depth is the depth to a claypan, bedrock, or any other layer in the soil that stops or greatly hinders the penetration by plant roots. Available waterholding capacity refers to the total amount of water available to plants to the effective depth of the soil (to a maximum of 5 feet) when the soil is at field-moisture capacity. This moisture content is approximately that of a well-drained soil two or three days after wetting.

Hydrologic soil groups are used for estimating the runoff potential of soils. Classification is based on conditions at the end of long-duration storms that occur after the soil is already wet and has had an opportunity to swell and is made without considering the protective effect of vegetation. Soils are divided into four groups according to soil properties that influence runoff:

Group A - Soils having high infiltration rates even when thoroughly wetted, consisting chiefly of deep, well- to excessively drained sands and/or gravel. These soils have a high rate of water transmission and a low runoff potential.

Group B - Soils having moderate infiltration rates when thoroughly wetted, consisting chiefly of moderately deep to deep, moderately well- to well-drained soils with moderately coarse textures. These soils have a moderate rate of water transmission.

Group C - Soils having slow infiltration rates when thoroughly wetted, consisting chiefly of soils with a layer that impedes the downward movement of water or soils with moderately fine to fine texture and a slow infiltration rate. These soils have a slow rate of water transmission.

Group D - Soils having very slow infiltration rates when thoroughly wetted, consisting chiefly of (1) clay soils with a high swelling potential, (2) soils with a high permanent water table, (3) soils with a claypan or a clay layer at or near the surface, and (4) shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission.

The Hydrologic Soil Groups Map on the next page shows the distribution of soils as classified above. Only the most prevalent hydrologic soil group is shown in each delineation. The infiltration rates used as a basis for the map were estimated.

The distribution of hydrologic soil groups in the basins is as follows:

	Area (Square Miles)	
Hydrologic Soil Group	Eel Basin	Mad Basin
A	55	9
B	2,375	620
C	925	255
D	550	45
Total	3,905	929

Unified Soil Classification System group symbols are shown for the subsoil texture of each soil series. The PCA Soil Primer of the Portland Cement Association (Chicago, 1962, 52 pp.) was used as a guide for grouping the soils according to this system.

An estimate of the severity of past sheet and gully erosion was made by examining aerial photographs of selected sample areas and by field checking. Areas that have excessive sheet erosion, gully erosion, or soil slips were delineated on the photographs. The delineated areas were categorized into the moderate or severe erosion classes, and the remainder of the area on each photograph was assumed to be slightly eroded.

The area of each erosion class was estimated by statistical methods from the eroded area of the samples. There are about 325 square miles in the moderate erosion class, which commonly has 5 to 10 lineal miles of gullies per square mile. About 70 square miles are in the severe erosion class, which commonly has 10 to 20 lineal miles of gullies per square mile. Past sheet and gully erosion has been most damaging to shallow or moderately deep soils that have been used for grazing. Approximately 45 percent of the Yorkville soils, 25 percent of the Maymen-Los Gatos soils, and 15 percent of the Laughlin soils are moderately or severely eroded. While the soil associations themselves differ in erodibility, the variations in the percentages subject to excessive erosion are mainly attributed to differences in use and management, as reflected by the vegetal cover density.

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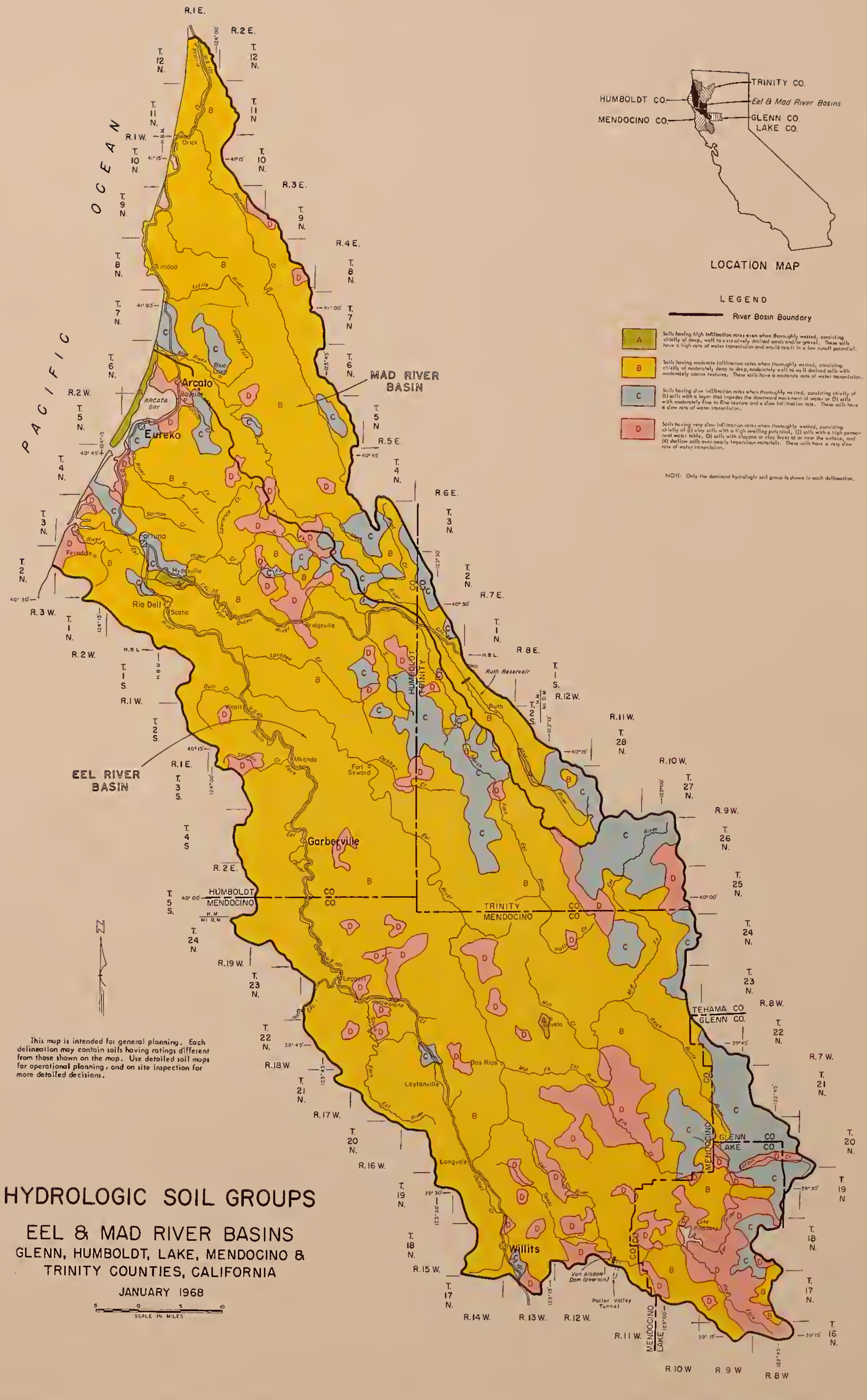

M7-S-20668-N

VEGETAL COVER TYPES

The delineations used on the Vegetal Cover Types Map at the end of this section were developed from the legends and supplemental information that accompany the Timber Stands and Soil-Vegetation Maps prepared by the Pacific Southwest Forest and Range Experiment Station and are defined as follows:

CONIFER: This broad classification consists of several forest types -- redwood, Douglas-fir, mixed conifer, pine, true fir, and minor conifer, such as knobcone pine. The redwood type occurs in the cool, moist belt along the western portion of both basins. The Douglas-fir type is found at medium elevations directly to the east of the redwood forest. The mixed conifer type is generally concentrated along the eastern boundary and contains mixtures of commercial pine and/or Douglas-fir, incense cedar, and true fir. Pine, fir, and minor conifer occur in isolated patches and comprise a very small percentage of the coniferous vegetation.

WOODLAND: The woodland type generally is a rather dense mixture of broadleaf trees and other woody vegetation. Tanoak, madrone, and black oak are the most common tree species and are often associated with Douglas-fir, redwood, California laurel, white alder, maple, brush, and herbaceous species. This type, together with the closely related woodland-grass type, forms a discontinuous belt up the central axis of the drainage.

WOODLAND-GRASS: The woodland-grass type is generally a low-density woodland stand with an understory of annual grass and many scattered grass-covered openings. This type was delineated in the Mad River Basin, but in the Eel River Basin it was included in the woodland type.

BRUSH: The brush type is a moderately dense mixture of chamise, scrub oak, manzanita, and associated species, such as ceanothus and Yerba Santa. Most of this type occurs in the southeastern part of the Eel River Basin, but it is often found in small patches within coniferous forest and woodland types in almost all areas of the Eel and Mad River Basins.

GRASS: A mixture of perennial and annual grasses and forbs of varying density generally comprise this type. Pure grassland occurs in some areas, but small clumps of oak or other woodland and brush species are scattered throughout much of the type.

The distribution of present vegetal cover and other elements by broad types is shown in the tabulation and on the Vegetal Cover Types Map on the following pages.

Vegetal Cover Type	Area (Square Miles)			Percent of Total Basin Area
	Eel Basin	Mad Basin	Total	
Conifer	1,407	351	1,758	36.4
Woodland	1,143	327	1,470	30.5
Woodland-Grass*		40	40	0.8
Brush	511	85	596	12.3
Grass	622	60	682	14.1
Barren	8	27	35	0.7
Rock	6	3	9	0.2
Cultivated, Urban, and Industrial	178	30	208	4.3
Reservoir and streambed	30	6	36	0.7
Total	3,905	929	4,834	100.0

LAND USE

Principal land uses, ranked in the order of relative importance, are timber production, agriculture, and recreation. The economy of the area has long been dependent on the development and utilization of timber. Agriculture, principally livestock production, provided the original impetus for settlement, but its relative importance has diminished. Recreation has become more important in recent years as a result of increased population and improved access.

The following tabulation shows the principal land uses for the various vegetal cover types in the Eel and Mad Basins:

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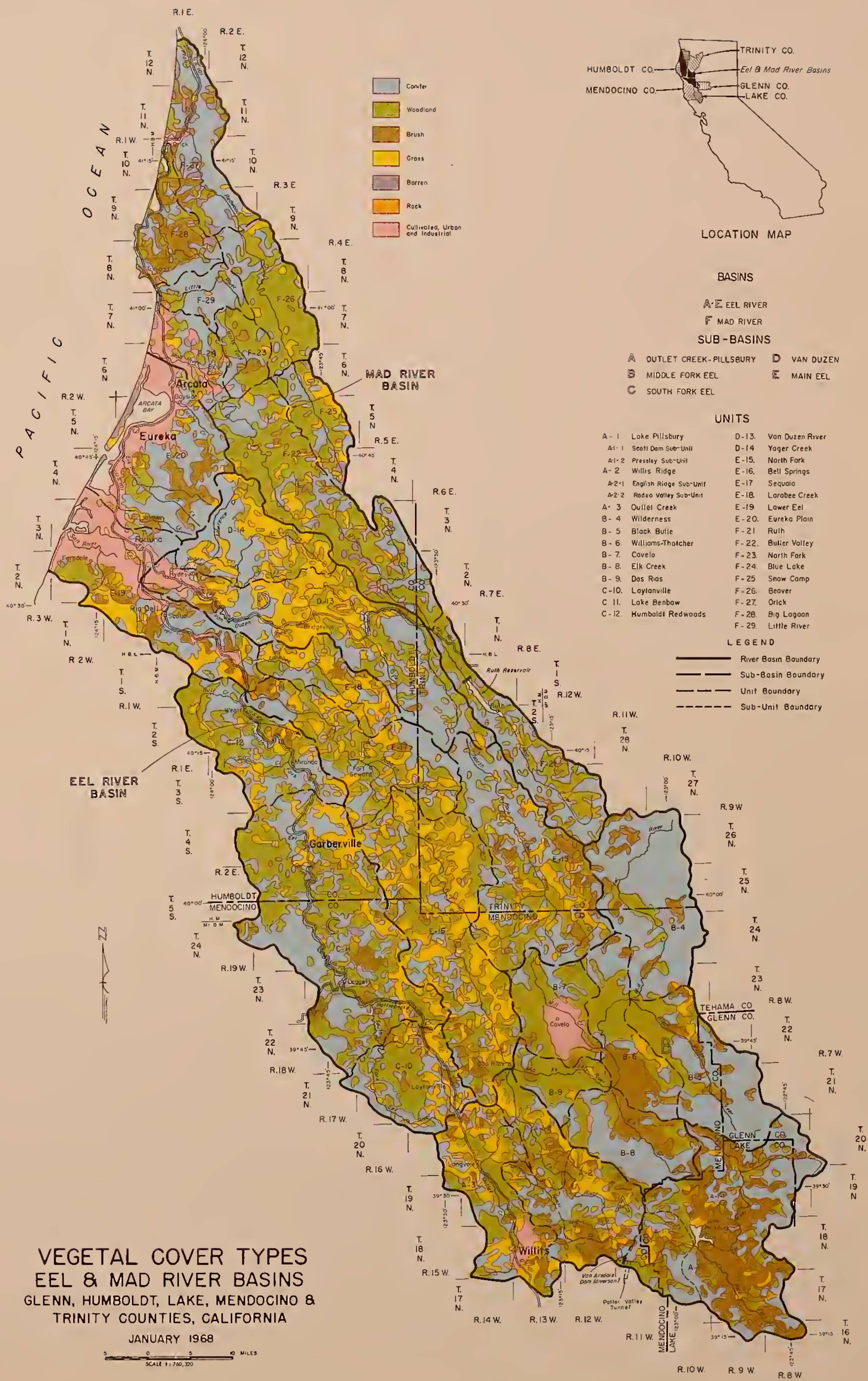
* Woodland-grass was recognized as a distinct vegetative type in the Mad Basin, but not in the Eel River Basin. The woodland-grass component was separated from the woodland type for sampling and analysis purposes in the Mad River Basin; however, for the sake of uniformity, it was not shown on the Vegetal Cover Types Map.



VEGETAL COVER TYPES
EEL & MAD RIVER BASINS
GLENN, HUMBOLDT, LAKE, MENDOCINO & TRINITY COUNTIES, CALIFORNIA

JANUARY 1968

SCALE 1:760,320

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

M7-S-18962-N

Vegetal Cover Type	Principal Land Use	Area (Square Miles)
Conifer	Estimated 50% timber production; recreation, grazing, and wildlife	1,758
Woodland	Grazing, recreation, and wildlife	1,510
Brush	Grazing, recreation, and wildlife	596
Grass	Grazing, recreation, and wildlife	682
Cropland	Pasture-grazing and row crop	164
Urban & industrial	- - - - - - - - - - - - - - - - - -	44
Barren & rock	Wildlife	44
Reservoir & streambed	Fishery, recreation, and water supply	36
	Total	4,834

Commercial fishing, mining, and service industries, such as trade, construction, transportation, communication, and utilities, affect land use to a varying extent.

National forest lands have long been administered under the management concepts of multiple use. These concepts were made law by the Multiple Use--Sustained Yield Act of June 12, 1960. This act provides that the various renewable surface resources be managed so that they are utilized in the combination that will best meet the needs of the people. Multiple-use plans for each ranger district consider the relative values of the various resources in particular areas. These plans attempt to maximize the benefits from these resources although they do not necessarily maximize dollar return or unit output.

TIMBER INDUSTRY

The timber industry developed soon after initial settlement of California's North Coastal Region and quickly became and has remained the most important segment of the economy. Much of the early timberland use was simply an exploitation of the timber resource with little regard for the future. Recently, however, emphasis has shifted to sustained yield management, particularly among the large timberland owners. National forest timberlands have long been managed for sustained yield.

Future demand for other land uses is expected to reduce the amount of land available for the production of forest products. Urban, rural residential, and recreational development, road construction, inundation by reservoirs, and needs for land for service facilities will encroach upon present timber producing lands. Conversely, some previously converted timberlands, which are presently grass-covered will probably revert to timber. In general,

however, it is expected that the amount of land used primarily for timber production will decrease somewhat in the future, but that the timber industry will remain a major component of the economy.

AGRICULTURE

The second most important land use is agriculture, principally livestock grazing, with some truck and field crop production. Most of the approximately 19,000 acres of irrigated pasture is located near the coast, but there are a few areas scattered throughout the remainder of the basins. Sheep and cattle are grazed throughout the basins, and dairy ranches are located in the Eel River Delta.

It is expected that agricultural use of the more level and accessible land will decrease because of urbanization around present communities and recreation development and inundation behind proposed dams. As a result, some of the less desirable lands will probably be utilized to meet demands for agricultural products. Grazing will probably not be as seriously affected by urban encroachment. However, some private rangeland along principal highways is being subdivided for summer home development, and this trend will probably increase in the future. In addition, some prime hunting, fishing, and recreational lands that are now being used for grazing will probably be dedicated solely to recreational use.

RECREATION

Recreation land use ranks third in importance to the economy. The diverse climate, topography, and vegetation, along with good hunting and fishing, make the basins extremely attractive to recreationists and tourists.

Most of the lands in the basins are used for some type of recreation, and many landowners sell hunting and fishing rights on their land to individuals or clubs during the appropriate seasons of the year. Since the heart of the Coastal redwood forest area is located in these basins, tourism, camping, and hiking are popular forms of recreation in the readily accessible areas. State parks and national forests receive heavy use in developed recreational areas; however, the basins have lagged in recreation development because of their remoteness from major population centers.

OTHER USES

Urban, rurban (a blend of rural and urban), and summer home development is expected to increase, and some prime agricultural and timber lands will be used for this expansion. Commercial fishing, while it occurs mainly in ocean waters adjacent to the river outlets, is substantially affected by salmon produced in the rivers. Additional water resource development could reduce the number of fish available for commercial harvest by lowering water quality, silting spawning beds, and reducing anadromous fish habitat. Mining activity in recent years has been limited primarily to sand and gravel production for construction and is expected to increase with population growth. The various service industries, such as transportation, communication, and utilities, will require more land in the future.

LAND OWNERSHIP

There are six types of land ownership within the basins, as shown in the following table and on the Land Ownership Map on the next page. The table and map were developed from records of various agencies and checked with data from county recorders' offices. Approximately three-quarters of the watershed area is privately owned.

Approximate Land Ownership of The Eel and Mad River Basins

Type	Area (Square Miles) Eel	Mad	Total	Percent of Total Land Area
Private Lands				
Individuals & Corporations	2,783	721	3,504	72.5
Indian Lands 1/	31	0	31	0.6
Subtotal	2,814	721	3,535	73.1
Public Lands				
National Forests	895	174	1,069	22.2
Public Domain	141	6	147	3.0
State Parks	39	25	64	1.3
Misc. State & County	16	3	19	0.4
Subtotal	1,091	208	1,299	26.9
Total	3,905	929	4,834	100.0

1/ Includes private Indian holdings and tribal lands within the reservation boundaries.

The Forest Service has direct management responsibility for most of the public lands. Portions of the Six Rivers and Mendocino National Forests comprise more than one-fifth of the basins' area, including the headwaters of most of the major drainages.

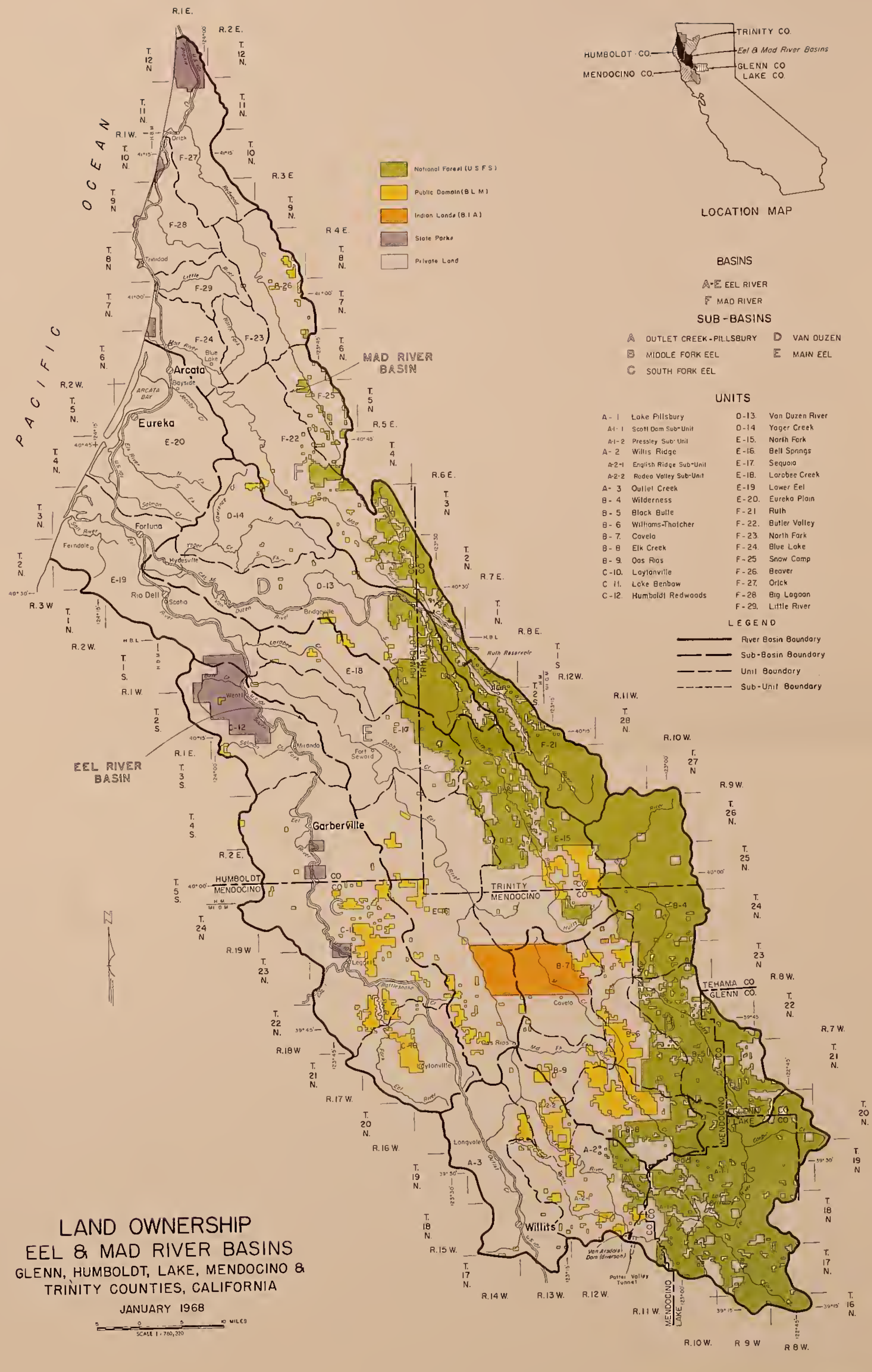
The U. S. Department of the Interior, Bureau of Land Management has the responsibility for the management of the public domain lands scattered throughout the basins.

The U. S. Department of the Interior, Bureau of Indian Affairs is the trustee of all natural resources on Indian lands, which total about 20,000 acres within the Eel River Basin. This land is located in the Round Valley Indian Reservation and in rancherias near Laytonville, Sherwood, and Rohnerville.

The California Department of Parks and Recreation is responsible for the care and management of several state parks and recreation areas within the basins, located mostly along Highway 101. Prairie Creek Redwoods, Patricks Point, Trinidad Beach, Dry Lagoon Beach, and Little River Beach State Parks are in the Mad River Basin; Humboldt Redwoods, Grizzly Creek Redwoods, Reynolds, Richardson Grove, Benbow Lake, Standish-Hickey, and Admiral William Standley State Parks are in the Eel River Basin.

Most of the forest lands in the Eel River and Mad River Basins are in private holdings. Most of the private timber lands outside the national forest boundary are owned in large blocks by major timber companies, especially in Humboldt County.

Private lands used primarily for grazing are scattered throughout the basins, with a noticeable concentration in the central belt of grass and woodland in and near the Main Eel Subbasin.



U S DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

M7-S-18966-N

P R O B L E M S

Problems presented in this chapter are those connected with sediment yield and are divided into two groups -- sediment and debris deposition and erosion. Sediment deposition problems have occurred to some extent with each flood in the basins. In recent years, flooding has occurred about every third or fourth year on the average; the two major floods of record took place in December 1955 and December 1964. Erosion problems occur each year, especially in the form of sheet and gully erosion and landslides, but the magnitude of these erosion problems is greatly increased during the periods of major flooding.

The Soil Conservation Service estimated the agricultural damages in the basins during the December 1964 flood to be $7.2 million,[1/] of which an estimated $1.4 million was directly attributable to erosion and deposition. A portion of the remaining damages is also associated with these two problems, but the amount was not estimated separately from floodwater damages.

SEDIMENT AND DEBRIS DEPOSITION

Sediment deposits usually consist of soil material -- silt, sand, and gravel -- while debris deposits generally include all other organic and inorganic materials, such as lumber, logs, fences, and trees.

DEPOSITION AREAS

The major deposition areas are located on the plains near the coast, along the old terraces adjacent to the main rivers and tributaries, in Round Valley, and in Little Lake Valley.

Agricultural

Most of the cropland in the basins is located in the Eel and Mad River Plains, Round Valley, and Little Lake Valley. Of the 133,000 acres of cropland, about 20,000 acres[2/] have been damaged by sediment and debris deposits.

Damages from sediment and debris deposition occur over most of the flooded area. In the December 1964 storm, the deposition varied from minor amounts to depths of 3 or 4 feet. Generally, crops are destroyed by these deposits and must be replanted. The sand and gravel portion of sediment deposits must be removed to waste areas, and the fields must be reshaped before planting. Logs, trees, and other vegetal debris must be stacked and

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1/ USDA Soil Conservation Service, Flood Damage Report, December 1964 - January 1965, an unpublished report. (Berkeley, 1965).

2/ James McLaughlin and Frank Harradine, Soils of Western Humboldt County, California, p. 4. (Davis; Department of Soils and Plant Nutrition, University of California, Davis, in cooperation with the County of Humboldt, November 1965).

burned or removed to a waste area. Irrigation pipelines must often be cleaned out, and pumps must be either overhauled or replaced.

In inundated areas, those farm buildings not washed away by the floods often have sediment and debris deposits in them that require considerable cleanup and repair. Farm equipment often must be dug out of the debris and overhauled before it can be used again.

Urban

During the December 1964 storm a number of communities were damaged by sediment and debris deposition that ranged from minor depths to several feet. Most of these communities are located in the Eel River Plain, in the narrow valleys along the Eel River up to Dos Rios, on the Van Duzen River, or on the South Fork of the Eel River. Deposition damage was less in urban areas than in agricultural areas.

Roads

During the December 1964 storm, removal of sediment and debris was required on a number of road reaches in the plains and along the major rivers and tributaries. Probably the largest deposition problem on roads came from landslides, which closed off a number of road reaches. Nearly every year, a few landslides take place that either hamper traffic or close roads.

CHANNEL DEPOSITION

As a result of the December 1964 storm, many reaches of stream channels, both large and small, had sediment deposits in varying depths up to 8 feet, and some are still aggrading today. The U. S. Geological Survey found that channel aggradation occurred at most of their gaging stations in the Eel River as a result of this storm. [1/] This problem appears to be temporary and, in time, degradation is expected to take place. Over a long period of time, the aggrading and degrading actions probably balance each other and, in general, the stream channel system appears to be in equilibrium. Sediment deposits are also found along the inside of curves and at confluences with tributaries. As the channel capacity is lessened by aggrading, the flooding problem in adjacent areas becomes greater.

Trees, brush, rocks, and soil are deposited naturally into streams, but man adds to the problem by allowing waste materials from lumbering, road building, and agricultural and domestic activities to accumulate in or near channels. As a result, debris jams sometimes form that reduce the cross-sectional area of flow, forcing the streams to overflow its banks. When these jams break up, the sudden rush of turbulent water accelerates the streambank erosion immediately downstream. Debris jams and floating debris have also damaged bridges, buildings, and other developments along the rivers.

1/ John J. Hickey, Variations in Low-Water Streambed Elevations at Selected Stream-Gaging Stations in Northwestern California, USDI Geological Survey Water Supply Paper 1879-E, (Washington, D. C., U. S. Government Printing Office, 1969). 33 pp.

Potential Future Problems

The present unregulated flows have the required capacity to transport the sediment yielded by the watershed to the ocean, but this state of equilibrium could be upset if large reservoirs were constructed on the main stem or major tributaries. A number of tributaries to the Eel River have high sediment yields, especially downstream of Fort Seward, and those located downstream of a large reservoir could change the stream regime below that point.

The following are the types of problems that could develop from the regulation of flow downstream of a reservoir:

1. Coarse material may be deposited at the confluence of tributaries and the main stem. Then both the main channel and tributary would aggrade upstream from the confluence, reducing the stream gradient and its sediment carrying capacity.

2. More fine material may deposit in the reaches where the sediment carrying capacity of the stream is reduced or along the banks where velocities are slowed by friction. These fines would promote the growth of phreatophytes, such as willows and cattails, causing further deposition and growth to encroach upon the channel. This buildup would change the capacity, stability, and general appearance of the stream, which is often a matter of concern.

3. In time, the deposition of this fine material on existing gravel beds may affect their suitability as spawning beds for anadromous fish. Reduction in spawning beds would, in turn, affect the fishing recreation in this area.

4. The regulated flows in the main stream may not possess sufficient momentum to counteract tributary flows entering at an angle and both streams could be deflected against the opposite bank, causing erosion and instability.

These potential problems are based on examinations of existing problems below Lewiston Dam on the Trinity River. Although the hydrologic and sedimentation regimes of the two rivers differ in scale, it appears they have sufficient similarity to warrant a word of caution.

During the final planning stages of large reservoirs, a detailed study should be made to predict the magnitude of the potential sediment deposition problem in channel reaches with regulated flows and to formulate remedial measures that will minimize or eliminate this problem. The solution may require large reservoir releases and construction of debris dams on heavy sediment-carrying tributaries to preserve fish, wildlife, and the natural beauty of rivers downstream of major dams.

DESTRUCTION OF FISH AND WILDLIFE HABITAT

Deep sediment deposition in bottoms of streams and rivers destroys the new crops of anadromous fish eggs and the natural fish and wildlife habitat. Deposition of fine material in these areas generally eliminates their use as future spawning areas for fish.

PERIODIC EFFECT ON WATER QUALITY

During the heavy winter runoffs, considerable suspended sediment is present in many small streams and most of the main rivers. This gives the water a brownish hue that often remains until June in some of the rivers and streams. In the upper Eel River, suspended colloidal material occurs in the water at Lake Pillsbury and at the Van Arsdale Reservoir. At the Van Arsdale Reservoir, some of the Eel River water is diverted for power generation and irrigation in Potter Valley in the Russian River Basin, and some of it reaches the East Fork of the Russian River. The same colloidal problem now exists in the Upper and East Forks of the Russian River.

Near the lower end of the Mad River, the Humboldt Bay Municipal Water District has installed several "Ranney" type collectors in the river bottom to obtain water supplies for industrial and municipal uses. These collectors pick up water below the river bottom at various levels down to 50 or 80 feet deep. The constantly shifting sands and finer sediment materials clog the natural filter beds in the river bottom, restricting the intake at the upper levels. Scraping the filter beds with bulldozers and back-flushing with water is required at least daily. The deeper intake levels continue to function properly, but their water supply is inadequate to serve industrial needs. Sediment taken in at the upper levels wears out the pump bearings and impellers, causing excessive maintenance costs.

RESERVOIR DEPOSITION

Sweasy Dam was constructed in 1938 on the Mad River with a storage capacity of 1,750 acre-feet and a diversion to supply water to the city of Eureka. By 1950, about 1,000 to 1,100 acre-feet of sediment had been deposited in the reservoir, and in 1954, this amount had increased to 1,600 acre-feet. The reservoir had completely filled with sediment by 1955, and the water supply project was abandoned.

Two other large reservoirs -- Lake Pillsbury on the Eel River and Ruth Reservoir on the Mad River -- have had light sediment deposition. These reservoirs are located in the upper areas of the basins, where the general condition of the watersheds is good and the sediment yield per square mile is lower.

The sediment deposition rate in smaller reservoirs varies from slight to very heavy, depending on the vegetal condition of the watershed. The useful life of a reservoir is considerably shortened when moderate or heavy sediment loads are deposited. In Round Valley, a privately owned reservoir with a 48-acre-foot capacity was completely filled with sediment during the December 1964 storm.

EROSION PROBLEMS

Erosion problems were grouped into four main sources for study -- streambank, landslide, road, and sheet and gully erosion. The first two sources provide the largest part of the total sediment yield.

LOSS OF PRODUCTIVITY AND LAND

Erosion problems associated with loss of productivity and land are presented for each source and cause of sediment yield.

Streambanks

Terraces and alluvial fills are the major materials subject to streambank erosion. They generally have steep banks that slough off as the toes are undercut by streams. Terraces are usually located in wide canyon bottoms and valley floors, while alluvial fills are generally deposited along the inside of curves and at confluences with tributaries. Sediment rates per mile are generally high in these areas. Narrow canyons with steep slopes and shallow soils produce less sediment from streambank erosion. Sloughing occurs as toes are undercut by stream flows, but the channel widening process is limited by underlying rock formations.

Most of the streambank erosion appears to be a natural occurrence, but some of it has been accelerated by man's activities, as discussed in the section "Channel Deposition". Some of the debris dams that suddenly release accelerate the streambank erosion immediately downstream. This erosive action could also trigger landslides, especially in steep narrow canyons.

Landslides

Most of the landslides take place under natural geologic, topographic, and climatic conditions that are common to the basins, and the removal of slope toes by stream action often appears to be the trigger. Sometimes man's activities, such as logging, road construction, and vegetal cover conversion, influence landslides by decreasing the stability in an already unstable area.

Once a slide has occurred, much of the surface area is left bare and subject to sheet and gully erosion. In addition, the soil material on the surface has been loosened, increasing the erosion hazard. The existing landslide is generally unstable and subject to further sliding if the toe is removed again.

Sheet and Gully Erosion

Grazing

Grazing land consists of predominantely sheep and cattle range and pastures. For more than a century, privately owned natural grassland and adjoining

forest land converted to grass have been subjected to heavy grazing.[1/] On much of the land, the more desirable species of grass have been eliminated, and the poor quality of forage will no longer support large numbers of livestock. Perennial rangeland vegetation has generally been replaced by annual cover. Approximately one-third of the grassland has insufficient vegetal cover to protect the soil from sheet and gully erosion. This problem is especially critical on private rangelands that are grazed year around. Analysis of field data indicates that the percentage of bare ground is probably the most important factor related to sediment yield from privately owned grassland.

Erosion on grasslands converted from timberlands has accelerated to the point that sediment yields per square mile from these converted areas are greater than those from natural grasslands. The acceleration is greater because the converted lands have more bare ground than the natural grasslands and the quality of grass cover is poorer. Timber soils are acid in reaction and tend to produce woody vegetation more readily than they do grasses. Because of the large percentage of bare ground on converted lands, the number of gullies and small, shallow landslides per square mile is greater than that on natural grasslands.

Under range allotment plans for national forest land, grazing use is periodically adjusted to the carrying capacity of the land. Some lands were destructively grazed before the national forests were established, and the resulting present lack of vegetal cover increases the current soil erosion rates. This overgrazing continued in some cases during the early years of Forest Service management, but now most of these lands have been closed to grazing because of the severe erosion hazard. The highly erodable Yollabolly soils on high ridgetops are prime examples of soils whose present sediment rate reflects this destructive overgrazing.

Logging

Poor logging practices have created several problems: an excessive number of skid trails, stream crossings, and landings; improperly located skid trails, landings, and spur roads; excessive amounts of slash and debris entering channels; excessive soil disturbance caused by tractor logging on steep slopes; and erosion of road fills caused by inadequate culverts in live streams crossed by temporary roads. The postharvest erosion control treatment of skid trails, landings, and temporary spur roads was often inadequate. For example, skid trails and landings were not drained, spur roads were not closed or drained, and temporary fills across intermittent stream channels were not removed. Logging affects soil erosion by temporarily removing vegetal cover and by disturbing soil during skidding and yarding operations and the construction of logging roads. Even when using the most up-to-date logging methods, some damage inevitably results.

1/ L. T. Burcham, California Range Land, An Historico-Ecological Study of The Range Resource of California, pp. 199-205. (Sacramento; California Department of Natural Resources, Division of Forestry, 1957.)

On national forest land, logging practices have improved considerably during the past 15 years. Areas logged prior to 1955 often show excessive and improperly located skid trails, landings, and spur roads and inadequate postharvest erosion control treatment. During the late 1950's, erosion control treatments became standard practice on national forest land. Since then, skid trails, landings, and spur roads have usually been properly located and treated with postharvest erosion control measures. However, the present sediment rates from logged areas in the national forests still reflect the 10-to-15-year old logging; these rates are higher than would be expected if the areas had been logged under present standards.

Deer

Although many game species of wildlife exist in the Eel and Mad River Basins, only the black-tailed deer greatly influence sediment yield. When deer populations are concentrated, their routes are well traveled, exposing wide paths to erosion. As deer feed in a brush field, they tend to walk around the shrubs as they eat, often creating a trail around each bush.

Land use practices in these watersheds, such as logging and type conversion, have been largely beneficial to deer, and the number of deer has increased. Stabilization of logged or burned areas is often delayed when brush and trees are heavily browsed by deer. They eat the tender shoots, retarding growth and preventing the formation of a crown canopy until growth has exceeded their reach. Field observations of widespread overbrowsing of forage and of severe trampling in many areas lead to the conclusion that present deer populations are excessive in relation to the available habitat. Heavy deer use prolongs the period of time that logged or burned areas are exposed to erosion.

Burning

The survey has shown that wildfire is not a major source of sediment in the Eel and Mad River Basins because the average annual acreage burned over by wildfire has been quite small. This is attributed to fine work by fire protection agencies and a cooperative public because the vast areas of woody vegetation and the dry summer climate create a high potential fire hazard. When fires occur on highly erodible soils, severe erosion usually results.

The average annual control burn acreage during the period from 1960 through 1965 ranges from three to ten times that burned by wildfires in the upper portion of the Eel River Basin. Control burning is less frequent in the South Fork Eel Subbasin and is rarely used in the Van Duzen Subbasin and Mad River Basin to the north.

Control burning in the basins is done for two reasons: (1) to convert and maintain conversions of timberland or brushland to grassland for grazing, and (2) to dispose of slash and debris in logged areas in order to reduce the fire hazard and to aid reforestation. Control burns that are used to convert vegetal cover provide the greatest portion of the sediment yield caused by burning. Slash and debris is disposed of in connection with sustained-yield timber harvesting. This operation is usually well planned

and carefully conducted to avoid undue soil disturbance and to minimize the chance that fire will escape.

Temporary Roads

Temporary roads provide access for various land uses. These roads are built to minimum standards and are designed only for short term use, usually less than one year. After abandonment, they are often permanently used by hunters and jeepers, maintenance is neglected, and high sediment yields frequently result.

Recreation

Although sediment yield from recreation is not a problem at the present time, it could become one in the future. Recreation use is expected to expand significantly as more recreation sites are developed and new and improved highways make these facilities more accessible. Haul roads constructed for logging operations in national forests are opening up new areas to recreation that were previously considered inaccessible to most types of recreation. This is probably true of private timberlands also. Careful planning and good construction methods are necessary in building facilities to prevent an increase in sheet and gully erosion.

Cropland

Erosion is not a problem on croplands because they are mainly in grass cover and are used mostly for forage production. In time, these lands are expected to be converted to intensified farming, and the potential erosion hazard will increase as this conversion takes place. Careful conversion and followup management of these lands will be essential to maintain erosion at a nearly natural rate.

Roads

The design and location of roads are important because they can cause landslides, aggravate streambank erosion, disrupt drainage patterns, require costly maintenance, immobilize communities during heavy storms, and reduce the overall esthetic value. Tourism and recreation in the Redwood Region are sometimes hampered because of poor road conditions or delays during summer maintenance periods.

The largest volume of sediment from roads is yielded by steep, bare road cuts. Surface erosion and sloughing occurs during storms and is accelerated when bank toes are undercut by road maintenance equipment. Excess material removed from road ditches and surfaces is deposited on the downhill side of roads, and a high percentage reaches the stream system.

Sediment yield also occurs at stream or gully crossings where culverts are lacking or plugged with debris. Misalignment of bridges and culverts in relation to stream channels causes turbulence and deflection of flows against erodible banks, and road fill encroachment upon the stream channel causes similar problems.

Inadequate surface and subsurface drainage produces varying amounts of sediment runoff from hillsides, rain falling directly on roadbanks forms rills, and sloughing occurs when slopes become saturated, usually from subsurface flows. Erosion in gutters is accelerated where culverts are inadequate in size and number. Where water is allowed to collect in large amounts on roads and to spill over at uncontrolled points, additional gullies, bank sloughing, and erosion of road fills occur. Some gully erosion occurs where culvert outlets are located in midair and discharge onto unprotected slopes. Other culverts outlet on unstable soils where no waterway previously existed and, unless energy dissipators are provided, gullies form on the slopes below the road.

Erosion is less on roads located near ridgetops than for those located on hillsides or near stream systems. Roads at lower elevations or through unstable areas pose constant problems because they intercept some surface and subsurface flows, the possibility of landslides is higher, and more sediment reaches the streams.

LIMITATION OF POTENTIAL LAND USE

Erosion reduces the maximum potential use of lands in the basins. Streambank and sheet erosion, along with floodwaters, prevent much of the cropland from being intensively farmed. As topsoil is removed by landslide, streambank, sheet, and gully erosion, the livestock carrying capacity of grassland is reduced, and in time, this erosion destroys its agricultural potential. Similar problems on timberland limit its potential for maximum production, and erosion of timberland converted to grassland may reduce its potential for reforestation. About 37 square miles of grassland and 7 square miles of converted timberland are in the severe erosion class and have lost all potential as productive lands. The best use that can be made of these lands is for watershed or wildlife areas.

ENDANGERED DEVELOPMENTS

Erosion of roads and railroads endangers lives, especially when landslides or washouts suddenly occur. Closing of roads hampers the transportation of goods, and travelers are inconvenienced. Tourism, an important form of recreation in the Redwood Area, is affected by closed roads and repair work. Communities are sometimes isolated and must depend on emergency airlifts for food and medical supplies.

Erosion of streambanks and gullies can cause destruction of adjacent houses and buildings and endanger lives. Utilities may be destroyed, and electrocution or explosions may result. Water supplies may be interrupted, and the hazard of disease increased. Existing flood control facilities may be undermined and destroyed.

INCREASED COST OF LAND OPERATIONS

Gully erosion reduces the efficiency of land operations and increases operating costs. Men and equipment must either work around these gullies or build temporary fills across them. Sometimes the temporary fills are not removed prior to the rainy season, and accelerated erosion results.

Gully erosion in grassland areas where livestock is unable to cross creates management problems and leads to uneven grazing or overgrazing. Temporary logging roads and ranch roads located in gullied areas are costly because they generally require heavy maintenance expenditures or relocation.

INCREASED RUNOFF RATES

Sheet and gully erosion removes the topsoil and reduces the potential for growing good vegetal cover, and runoff increases proportionately with the reduction in vegetal cover. After timber is harvested, a large increase in runoff occurs because of the bare open area that remains. The amount of runoff decreases each year as reforestation takes place, and by about the seventh year, the runoff has returned to its original rate. The largest increase in runoff occurs when timberland is harvested and the land is converted to grass cover, particularly if the area is burned periodically to maintain the conversion. When croplands become intensively cultivated, the runoff from these lands will increase.

DESTRUCTION OF RECREATIONAL AND ESTHETIC VALUES

The ugly scars formed on land by erosion destroy the natural beauty of the area, lower land values, and reduce the recreation potential. Since people prefer to visit areas with beautiful surroundings, the two major forms of recreation -- tourism and camping -- are directly affected by the general appearance of an area.

DESTRUCTION OF FISH AND WILDLIFE HABITAT

Anadromous fish spawn in gravel bars located along rivers and streams, and the erosion or movement of these bars can destroy the egg crop and the spawning site. Land erosion affects wildlife since vegetation needed for feed and cover is destroyed and wildlife becomes concentrated in other areas.

ADVERSE IMPACT ON LOCAL ECONOMY

As the grass forage production is reduced through overgazing and erosion, the carrying capacity of the land is lowered and the livestock producer receives less income. Timberland owners also experience reductions in income when timber production is decreased or destroyed by erosion. These producers, in turn, spend less money with local supporting industries and businesses. As the general economy of an area is reduced by the loss of this income, the underemployment of that area is increased accordingly.

SEDIMENT YIELD STUDIES AND SURVEY PROCEDURES

SCS PHOTO 3-4654-13

"Sediment deposition at Weott, California, after the flood of December 1964."

This chapter describes the sediment yield studies and presents the results. Future sediment yields that could be expected by the year 2020 were predicted assuming that a land treatment program is not installed. The total sediment yield was divided into four principal sources -- sheet and gully, streambank, landslide, and road erosion -- and each was studied separately.

The Eel and Mad River Basins presently yield an estimated 14,345 acre-feet of sediment annually from 4,834 square miles of watershed, or an average of about 3 acre-feet of sediment per square mile per year. Streambanks, landslides, sheet and gully erosion, and roads yield about 64, 25, 10, and 1 percent, respectively, of the total sediment. The map on the following page, "Annual Sediment Yield," shows the present sediment rate for the hydrographic units in the basins.

The following table summarizes the present annual sediment yield by principal source and subbasin.

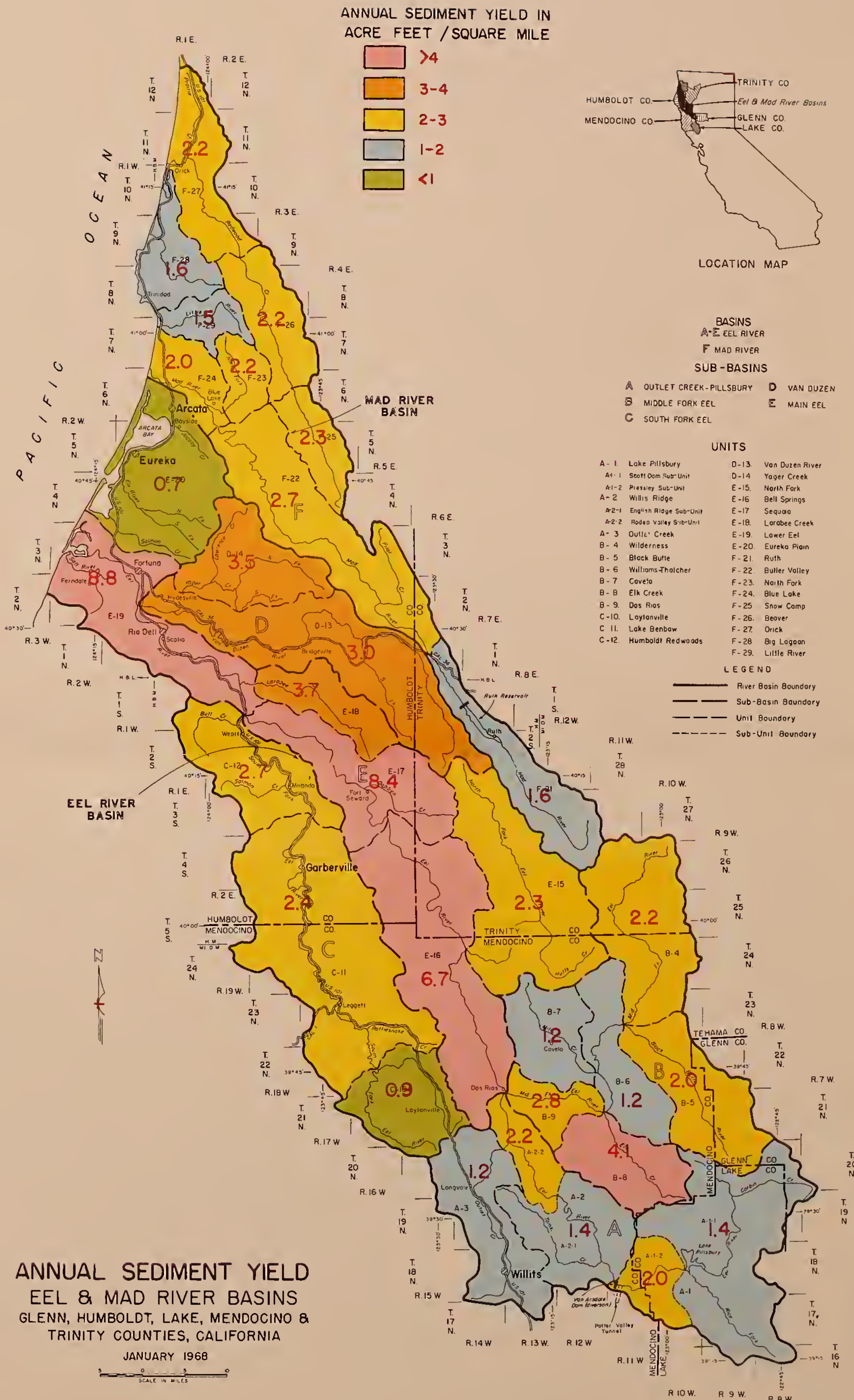
Subbasin	Present Sediment Yield (Acre-feet per Year) Stream-banks*	Land-slides	Sheet and Gully	Roads*	Total
Outlet Creek-Pillsbury	464	188	360	19	1,031
Middle Fork	1,026	366	225	16	1,633
South Fork	715	621	182	15	1,533
Van Duzen	753	474	108	6	1,341
Main Eel	4,996	1,517	299	11	6,823
Eel Basin Subtotal	7,954	3,166	1,174	67	12,361
Mad Basin Subtotal	1,304	449	226	5	1,984
Basins Total	9,258	3,615	1,400	72	14,345

* As defined and described on pages 54, 57, and 75.

The predicted future sediment yield without a program would be increased to 15,223 acre-feet annually, or about 3.1 acre-feet per square mile per year. The increase in sediment yield would come from landslide and road erosion, which are expected to accelerate because of increased use of watershed lands.

The following table presents predicted future sediment yield by principal source and subbasin without the installation of a land treatment program.

Subbasin	Future Sediment Yield Without Program (Acre-feet per Year) Streambanks	Landslides	Sheet and Gully	Roads	Total
Outlet Creek-Pillsbury	464	234	350	38	1,086
Middle Fork	1,026	456	210	32	1,724
South Fork	715	773	168	30	1,686
Van Duzen	753	590	102	12	1,457
Main Eel	4,996	1,888	293	22	7,199
Eel Basin Subtotal	7,954	3,941	1,123	134	13,152
Mad Basin Subtotal	1,304	559	198	10	2,071
Basins Total	9,258	4,500	1,321	144	15,223



ANNUAL SEDIMENT YIELD
EEL & MAD RIVER BASINS
GLENN, HUMBOLDT, LAKE, MENDOCINO & TRINITY COUNTIES, CALIFORNIA
JANUARY 1968

SHEET AND GULLY EROSION

Sheet and gully erosion contributes about 1,400 acre-feet per year, or nearly 10 percent of the total sediment yield of the basins. This source of sediment yield was classified according to causes that are discussed in detail in this section.

FOREST SERVICE PHOTOS

AVAILABLE DATA

Aerial photographs taken in 1941, 1944, 1948, and 1965 and the latest editions of U. S. Geological Survey Topographic Quadrangles were used extensively.

Wildfire and control burn records for private land were obtained from the California Division of Forestry. The records used in the survey covered the years 1945-64 for the Middle Fork Subbasin, 1961-65 for the rest of the Eel River Basin, and 1960-66 for the Mad River Basin. For the Mendocino and Six Rivers National Forests, wildfire data were secured for the periods 1950-66 and 1960-66, respectively.

The California Division of Forestry supplied a complete tabulation and map of logging for the 1955-64 period for the private land in the Middle Fork Subbasin. For the remaining area, the logging on private and national forest land was mapped from 1965 aerial photographs and national forest records.

SURVEY PROCEDURES

A category map was developed. A category is defined as a specific combination of mappable factors that affect soil erosion and sediment yield rates. Four major factors were selected: soil combined with slope, vegetation, land use, and land ownership. Land ownership was significant only in formulating the land treatment program. These were divided, respectively, into 40 soil-slope associations, 6 vegetal types plus bare ground and rock, 8 land use classes, and 2 land status classes to define major differences in erosion and sediment yield potential. The category map shows the area and distribution of each combination and was used to prorate the number of field samples among the categories and to expand the sample data over the basins.

The soil-slope association, vegetal cover type, and land status maps used to compile the category map are described in the chapter "Land Resources and Use."

The six vegetal types were redwood, conifer other than redwood, woodland, woodland-grass, brush, and grass. In the Mad River Basin, redwood and woodland-grass were segregated, but in the Eel River Basin they were included in the conifer and woodland types, respectively. Bare ground and rockland were treated as vegetal types that represent the absence of vegetation. As a vegetal cover type, bare ground most frequently occurred in recently cutover timber stands that are expected to become covered by some type of vegetation in the near future.

Types of vegetal conditions were delineated as follows:

- Undisturbed by Man
- Logged Condition
- Logged Condition and Burned
- Type-Converted
- Type-Converted and Burned
- Burned by Wildfire
- Cultivated
- Urban

Grazing was not delineated because there were no records that showed the area being grazed. This area was determined by field sampling.

Land classified as being in a logged condition is that which shows distinct skid trails and landings on aerial photographs. Field sampling revealed that logged areas on which skid trails or landings are not distinct on aerial photographs are presently eroding at a nearly natural rate.

A large proportion of the watersheds' original timberland has been logged, but only the land logged during the past 10 to 15 years still shows the effects of logging and is classified as being in a logged condition.

To evaluate the effects of national forest multiple-use management, land ownership was classified into two categories -- national forest and lands outside the national forests. Under multiple-use management each parcel of land is managed for more than one use. While lands outside the national forests have been managed essentially for single purposes, some owners of these lands have begun to employ multiple-use management.

The survey used Amidon's Alphanumeric Map Information Assembly and Display System (MIADS2)[1/], which converts conventional map data into two-character alphanumeric symbols. To develop the category map for this study, the left character was used to describe soils, slope, and land status, and the right character to describe vegetation and land use.

After the area in grid cells (representing about 85 acres each) was coded, the coded map data was punched on cards and fed into a computer, which yielded a coded category map, tables of the category areas, and the total watershed area.

Field sampling was based upon the category map and tables. Categories representing over one percent of the watershed area were selected for sampling, and those less than one percent were combined with similar categories unless they had a special significance. Approximately 90 categories were sampled out of the nearly 600 coded. The number of sample transects within a category was based upon its area and distribution. Transects selected to best represent each category were located on aerial photographs before going to the field; to conserve time, most were located within a 15-minute walking distance from roads. Each transect contained a series of 1/4-acre plots; approximately 1,800 plots were field sampled.

During the survey, forms for recording field data on sheet and gully erosion were developed; a sample showing typical data is presented on the following pages.

1/ Elliot L. Amidon, <u>MIADS2, An Alphanumeric Map Information Assembly and Display System for a Large Computer</u>, U. S. Forest Service Research Paper PSW-38, (Berkeley, Pacific Southwest Forest and Range Experiment Station, 1966). 12 pp.

USDA RIVER BASIN SURVEY - CALIFORNIA

RECORD FORM FOR INVESTIGATION OF AREAS BURNED, LOGGED OR GRAZED

MIADS - Category 4 pvt. Redwood

Sample No. 8N Party Cannon W Date May 8, 1967

Basin Mad Subbasin Lower Unit North Fork

Sample location: T. 6 N, R. 2 E, Sec. 11, ¼ Sec. NW

Aerial photo No. 20FF143 Yr. Flown 65 Land Status Pvt. Timber Land

Years logged —— Years burned ——

Predominate Land Use Timber production

Item	Plot 1	Plot 2	Plot 3	Plot 4
General				
Site photos taken	——	——	——	
B&R___Color___Stereo___	——	——	——	
Aspect	S	S	S	
Slope - Minimum	50	5	30	
Maximum	65	30	50	
Average	55	15	40	
Total length of slope (ft.)	300	200	125	
Length of slope below plot (ft.)	200	50	20	
Slope morphology	Uniform	Uniform	Uniform	
Plot Area (Acres)	0.25	0.25	0.25	
Vegetation General Type	Mixed Conifer	Douglas-fir	Redwood	
Dominate species	Douglas-fir Redwood	Douglas-fir Redwood	Douglas-fir Redwood	
Composition % Trees	98	95	80	
% Brush	1	1	5	
% Herbaceous	1	4	15	

Item	Plot 1	Plot 2	Plot 3	Plot 4
Effective Crown Density	80	65	60	
% Ground Covered By Live Groundcover	10	30	45	
Litter	89	70	45	
Bare Ground	1		5	
Rock	-		5	
Geology	——	——	——	
Soil Series	Melbourne	Melbourne	Melbourne	
Texture topsoil	S. C. L.	S. C. L.	S. C. L.	
Est. effective depth of soil	Deep	Deep	Deep	
Average Litter Depth	2"	1"	2"	
Type of Litter	Conifer & Hardwood	Conifer & Forbes'	Hardwood Conifer & Grass	
Distribution of Litter	Uniform	Uniform	Uniform	
% Area Disturbed By			Old Skid Trail	
Logging Skid Trails		0	5	
Spur Roads				
Landings				
Burns				
Grazing				
Deer	1	T	20	
Roads				
Other ______________				
Erosion - Sheet				
Past (class)	Very Slight	Slight	Slight	
Present (trend)	Static	Healing	Healing	
Ave. Topsoil loss (inches)	Trace	Trace	0.1	

Item	Plot 1	Plot 2	Plot 3	Plot 4
Erosion - Sheet (cont.)				
Est. % to stream	0	0	40	
Est. % Sedimentation by cause				
Deer	100		70	
Skid Trail			30	
Erosion - Gully Number of gullies	—	—	1	
Total length (feet)			70	
Ave. gradient (%)			50	
Ave. cross-sec. (sq. ft.)			15	
Est. % to stream			100	
Sediment production				
Est. % sedimentation by cause				
Deer			10	
Skid Trail			90	
Gully erosion trend			Healing	
Slides (Yes or No)	None	None	None	
Slide form completed				
Cause of Erosion (Explanation) Burn (Intensity)				
Logging (Type)			Tractor	
Landings (Location w/ref. to Str.)				
Skid trails (Location w/ ref. to Str.)			Adjacent	

Item	Plot 1	Plot 2	Plot 3	Plot 4
Cause of Erosion (cont.) Spur roads (Location w/ref. to str.)				
Grazing				
Deer			Trailing & Browsing	
Other ________				
Existing Treatment Seeding			None	
Planting				
Other ________				
Is present land management adequate?	Yes	Yes	No	
Additional Remedial Treat. Sug. Seeding (acres)				
Tree planting (acres)				
Gully Stabilization Gully plugs (No.)				
Contour trenches (acres)				
Diversions (length)				
Outlet conditions				
Fencing				
Fertilization				
Waterbars			2	
Other				
Management Suggestions Increased Fire Protection				
Change logging practice			Skid Trails Away from Str.	
Change grazing practice				
Change in land use				

Item	Plot 1	Plot 2	Plot 3	Plot 4
<u>Management Suggestions</u> (cont.)				
Wildlife Management				
Stock water development				
Recreation				
Other				

Suggestions for optimum land use management: Plot #3. At time of logging (30 years ago), two waterbars in this skid trail would have prevented the gully erosion. Deer trailing and browsing of Douglas-fir reproduction is perpetuating the erosion in the skid trail.

Remarks: Except for the skid trail in Plot #3, the logged area is in good condition.

DATA ANALYSIS

The field data for forest and brush covered lands outside the national forests and all lands within the national forests were tabulated, summarized, and averaged by categories. The depth of sheet and gully erosion was converted to acre-feet per square mile per year for each 1/4-acre plot. Then the soil erosion rate was plotted as a function of percent bare ground by slope classes on semilogarithmic paper; a sample graph is presented on the following page. A multiple correlation analysis revealed this relationship to be significant. For each category, the average percent bare ground and slope were projected into the curves to determine the average soil erosion rate, which is not significantly affected by extremes of percent bare ground or slope. With the relationship between the erosion rate and percent bare ground established, the effects of the remedial programs could be evaluated quantitatively on the basis of their effect upon bare ground.

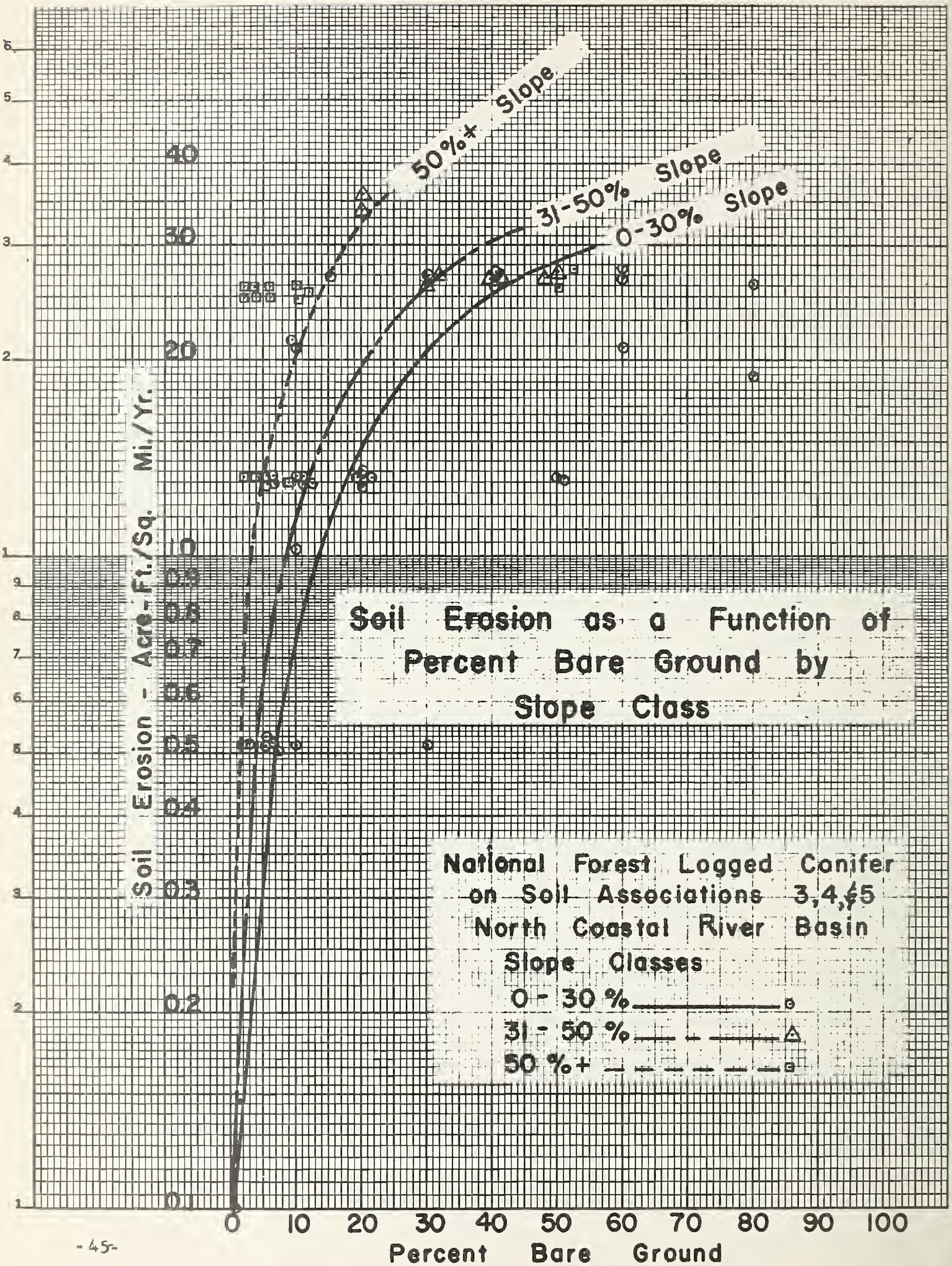
The projected soil erosion rate was multiplied by the average percent to stream to produce the sediment yield rate for the category. For example, if a category had a soil erosion rate of 1.0 acre-feet per square mile per year and averaged 50 percent delivery to streams, then the sediment yield rate would be 0.5 acre-feet per square mile per year. The sediment yield rate was multiplied by the category area to determine the total estimated sediment yield for the category. The sum of sediment yields from all categories is the total estimated sediment yield from sheet and gully erosion for these lands.

For privately owned grasslands and public grasslands outside the national forests, including cultivated land and irrigated pasture, similar categories were delineated. These categories were then separated into slight, moderate, and severe erosion classes, as described in the soils section of the chapter "Land Resources and Use," by inspecting aerial photographs on a sample basis, and these separations were checked in the field. The area of each erosion class was computed for each category, and field sample locations were selected on the basis of these areas. An average sediment rate was computed from field transect data for each erosion class in the grassland category. The computed sediment rate for each category is an average that is weighted according to the area and sediment rate of each erosion class in the category. The weighted rate times the category area determined the sediment yield from these grassland categories.

Sediment yield data from all lands were combined to arrive at the total estimated sediment yield from sheet and gully erosion.

Sediment yield by causes was calculated for the whole watershed. For example, if field observations indicated that half of the sediment yield for a category was due to logging and the rest to grazing, then the sediment yield for that category was divided accordingly. For the basins, the total sediment yield from a cause is the sum of the contributions of each category for that cause.

The sediment yield data for sheet and gully erosion were adjusted to be comparable with data for streambanks and landslides. Sheet and gully erosion data were calculated for the 10-year period 1956-1965, while


Soil Erosion as a Function of Percent Bare Ground by Slope Class
National Forest Logged Conifer on Soil Associations 3,4,&5
North Coastal River Basin
Slope Classes
0 - 30 %
31 - 50 %
50 %+
50%+ Slope
31-50% Slope
0-30% Slope
Soil Erosion - Acre-Ft./Sq. Mi./Yr.
Percent Bare Ground
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
20
30
40
0
10
20
30
40
50
60
70
80
90
100

streambank and landslide data covered 24 years, water years 1942-1965. The sediment yield data for sheet and gully erosion were adjusted by using a relationship between suspended sediment yield data and the sum of the highest daily mean discharge for 3 days (not necessarily consecutive). The 3-day period was selected because the annual suspended sediment yield measured at the gaging station "Eel River at Scotia" is significantly correlated to these 3-day flows.

The methodology is discussed in the addendum "Special Sediment Studies." The 24-year average sum of the highest daily mean discharge for 3 days is 63 percent of that for the 10-year period. Therefore, the 10-year sediment yield data were multiplied by 63 percent. It was assumed that this adjustment would make the 10-year sediment yield data from sheet and gully erosion comparable to the 24-year data for landslides and streambanks.

PRESENT SEDIMENT YIELD

Present sediment yield from sheet and gully erosion is summarized by causes for each hydrographic unit, subbasin, and basin in the table on the following page.

Some observations can be drawn from these data. The average annual sediment rate from sheet and gully erosion is 1,400 acre-feet per year, or 0.29 acre-feet per square mile per year, as shown in the second table following this page. The lowest average annual rate was 0.10 acre-feet per square mile per year for the Eureka Plain Unit, and the highest was 0.71 for the Scotts Dam Unit.

Sediment yield from sheet and gully erosion was attributed to seven causes, with natural erosion being the largest contributor. Natural erosion contributes 546 acre-feet per year, or 39 percent of the total sediment yield from sheet and gully erosion. The natural sediment rate is only 0.11 acre-feet per square mile per year, but when this rate is multiplied by the large acreage in which it occurs, the area is shown to produce a large volume of sediment.

Some soils have a high inherent erodibility. For example, Sheetiron and Masterson soils apparently have an average natural sediment rate of approximately 0.3 acre-feet per square mile per year for the 315 square mile area of these soils and Maymen and Los Gatos soils apparently have an average natural sediment rate of approximately 0.7 acre-feet per square mile per year for a 275 square mile area. When a catastrophic event or gross disturbance denudes an area of these type soils, erosion may persist for several decades. Since the original cause of the disturbance is not always apparent when the area is sampled many years later, sediment yield may be assigned to natural causes when it actually is the residual effect of some early influence of man.

Grazing was the second highest contributor, producing 357 acre-feet per year, or 25 percent of the total sheet and gully sediment yield. The average annual sediment rate caused by grazing is 0.32 acre-feet per square mile per year from 1,120 square miles. The 1,120 square miles includes about 762 square miles of privately owned grassland, 208 square miles of

Average Annual Sediment Yields from Sheet and Gully Erosion by Causes
for the Eel and Mad River Basins Under Present Conditions

Basins, Subbasins, and Watershed Units	Area (Square Miles)	Total (Acre-Feet/ Year)	Directly Influenced by Man: Logging	Burning	Grazing	Temporary Roads	Other: Deer	Natural
			(Acre-Feet Per Year)					
EEL RIVER BASIN								
Outlet Creek-Pillsbury Subbasin								
Lake Pillsbury	347	227	10	3	10	2	64	138
Scott Dam Subunit	(287)	(204)	(9)	(3)	(8)	(2)	(58)	(124)
Pressley Subunit	(60)	(23)	(1)	(0)	(2)	(T)	(6)	(14)
Outlet Creek	163	41	2	T	12	0	7	20
Willis Ridge	199	92	3	4	21	0	8	56
English Ridge Subunit	(142)	(65)	(2)	(4)	(11)	(T)	(6)	(42)
Rodeo Valley Subunit	(57)	(27)	(1)	(T)	(10)	(0)	(2)	(14)
Subtotals	709	360	15	7	43	2	79	214
Middle Fork Subbasin								
Wilderness	205	70	7	6	13	3	14	27
Black Butte	162	66	14	2	13	1	11	25
Williams-Thatcher	116	30	1	T	8	T	6	15
Covelo	99	14	1	0	7	0	T	6
Elk Creek	115	29	4	T	9	T	4	12
Dos Rios	56	16	2	T	7	0	2	5
Subtotals	753	225	29	8	57	4	37	90
South Fork Subbasin								
Laytonville	125	37	5	1	10	T	7	14
Lake Benbow	413	118	32	2	36	0	18	30
Humboldt-Redwoods	152	27	6	T	10	0	3	8
Subtotals	690	182	43	3	56	T	28	52
Van Duzen Subbasin								
Yager Creek	132	33	5	T	15	0	2	11
Van Duzen River	297	75	16	1	28	1	7	22
Subtotals	429	108	21	1	43	1	9	33
Main Eel Subbasin								
North Fork	283	105	2	T	17	1	21	64
Bell Springs	335	88	3	1	42	0	3	40
Sequoia	187	30	5	T	13	T	2	10
Larabee Creek	84	19	3	T	9	T	1	6
Lower Eel	214	35	5	T	21	0	1	8
Eureka Plain	221	22	4	T	11	0	1	6
Subtotals	1,324	299	22	1	113	1	29	134
EEL RIVER BASIN TOTALS	3,905	1,174	130	20	312	8	182	523
MAD RIVER BASIN								
Ruth	143	33	2	0	2	0	22	7
Butler Valley	250	80	34	1	22	T	15	8
North Fork	47	9	4	T	2	0	2	1
Blue Lake	65	6	1	T	3	0	T	2
Subtotal	505	128	41	1	29	T	39	18
Little River	46	3	1	T	1	0	1	0
Big Lagoon	84	8	4	0	2	T	2	0
Subtotals	130	11	5	T	3	T	3	0
Snow Camp	68	18	9	T	5	0	2	2
Beaver	107	28	16	T	6	0	4	2
Orick	119	41	34	T	2	0	3	1
Subtotals	294	87	59	T	13	0	9	5
MAD RIVER BASIN TOTALS	929	226	105	1	45	T	51	23
EEL AND MAD RIVER BASIN TOTALS	4,834	1,400	235	21	357	8	233	546

Present Sediment Production Regime From Sheet and Gully Erosion For The Eel and Mad River Basins

Cause of Sedimentation	Average Annual Sediment Yield (Acre-Ft./Yr.)	Percent of Total	Approximate Gross Area Sampled (Square Miles)	Sediment Rates: Average (Acre-Feet/Square Mile/Year)	Sediment Rates: Highest Recorded (Acre-Feet/Square Mile/Year)
Directly Influenced by Man					
Logging	235 1/	17	562 2/	0.36 3/	34.30
Burning	21	1	60 4/	0.35	2.69
Grazing	357	25	1,120	0.32	12.70
Temporary Roads	8	1	-- 5/	--	0.56
Other					
Deer	233	17	4,546 6/	0.05	7.55
Natural	546	39	4,834	0.11	14.70
Total	1,400	100		0.29	

1/ This volume is the sum of the sediment yielded by logging on land classified as being in a logged condition (201 acre-feet/yr.) plus the sediment yielded by the effects of logging on land classified into other categories (34 acre-feet/yr.).

2/ This is the area of land classified as being in a logged condition.

3/ This rate equals the sediment yielded by logging on land classified as in a logged condition, divided by the area of the land classified as in a logged condition (201 acre-feet/yr. ÷ 562 sq. miles = 0.36 acre-feet/sq.mile/yr.)

4/ Area of control burns and wildfires for 1960-65 in the Eel River Basin and 1960-66 in the Mad River Basin that were in California Division of Forestry and U. S. Forest Service records.

5/ Data on the area of temporary roads within the Eel and Mad River Basins were not available; see page 50 for a definition of temporary roads.

6/ See page 49 for an explanation of this area.

cropland and urban-industrial use, 32 square miles of miscellaneous land use and 118 square miles of national forest.

The main sediment sources affected by grazing were the 562 square miles of privately owned natural grassland (range) and the 200 square miles of timberland converted to grass. The sediment yields from these sources are presented in the following table:

Erosion Class	Area (Square Miles)	Sediment Yield (Acre-feet/Year)
Natural Grassland		
Slight	376	58
Moderate	149	94
Severe	37	81
Subtotal	562	233
Converted Timberland		
Slight	158	37
Moderate	35	34
Severe	7	24
Subtotal	200	95
Totals	762	328*

*Includes about 100 acre-feet resulting from natural causes.

The third most important sediment producer is logging. The 562 square miles of land in a logged condition yielded 201 acre-feet of sediment per year. On land classified as being in other than a logged condition, the residual effects of old logging and the impact of adjacent logging yielded an additional 34 acre-feet per year. Logging caused an estimated 17 percent of the total sediment from sheet and gully erosion. Sediment rates average 0.36 acre-feet per square mile per year for the area classified as logged.

Deer use is another cause of sediment yield, contributing 233 acre-feet per year, or 17 percent of the total sheet and gully erosion. The sediment rate per square mile for deer damage is only one-seventh of that for logging, averaging 0.05 acre-feet per square mile per year, although the total sediment yield is about the same. This cause was separated from natural sediment yield because deer numbers and habitat can be managed. Deer use virtually the entire Eel and Mad River Basins, but they tend to congregate in openings created by logging or burning.

Wildfire and control burns have not been an important cause of sediment, yielding only 21 acre-feet per year. Records show that only 60 square miles were burned between 1960 and 1966 in the basins, but they do not include the control burning done in the winter. The sediment rate from fire averaged 0.35 acre-feet per square mile per year and ranged between a trace to 2.69 acre-feet per square mile per year. This relatively high rate indicates that potential damage from fire is high and that significant on-site soil losses could result.

Sediment yield from temporary roads averages 8 acre-feet per year. Because temporary roads presently cover only a small area, their sediment yield is low; however, the sediment rate per mile is high, indicating that a significant problem could occur as more roads are built.

Because rodent activity caused less than 1 acre-foot of sediment per year, it is not considered a significant contributor and was not included in the table as a cause. The highest observed sediment production rate for rodents was 0.18 acre-feet per square mile per year.

FUTURE SEDIMENT YIELD

The future sediment yield from sheet and gully erosion will drop from the present yield of about 1,400 acre-feet per year to about 1,321 acre-feet per year by the year 2020 without the installation of a land treatment program. The reduction will result from improved logging methods, while most of the other land management practices will continue to cause sediment yield at about the present rate. Future sediment yields from the grazing of private grassland are expected to increase about 10 percent, but this amount would be offset somewhat by improved management on other grazing land.

Before the future sediment yield from sheet and gully erosion could be predicted, it was necessary to estimate the level of management that would occur. Because of various factors relating to land values, population pressures, changing public concerns, and the modification of traditional methods of operation, it is expected that land use and management will improve even if the management guidelines and remedial measures recommended in this appendix are not followed. To arrive at some measure of this improvement, the following set of assumptions were developed with the help of local, state, and Federal government officials, private landowners, and publications of various study groups and researchers. These assumptions provided the framework for deriving future sediment yields without installation of a land treatment program.

Timber Management Assumptions

1. Logging of privately owned land is expected to be continuous during the next 50 years although the pace will slow down during the next 30 to 40 years as the remaining supply of old-growth timber is harvested. Logging will then accelerate as second-growth timber reaches commercial size.

2. Many small parcels of timber will be purchased by large lumber companies, which already own most of the private timberland, or the timber stands may be liquidated as smaller trees are harvested for studs and pulp to satisfy the increased demand for these products.

3. Large timber companies are gradually adopting sustained-yield management and are expected to operate on rotations of about 60 years for saw logs and 30 years for poles. Under sustained-yield management there will be more emphasis on regeneration of timber stands, and some brush fields will be converted to timber.

4. Where a stable water supply is available and problems of water and air pollution can be solved, the pulp and paper industry will become established. This will allow the utilization of smaller wood material, making thinning of stands profitable and promoting more efficient use of all the wood produced.

5. The need for raw material for pulp and paper will lead to the harvesting of marginal timberlands, which will disturb lands that would not otherwise have been logged and will probably increase sediment yield. Many of these marginal lands will not regenerate easily, and some will become brush fields.

6. Logging practices on privately owned lands are expected to improve because of public pressure, legislation requiring watershed protection measures, increases in land values, and a more enlightened attitude towards resource conservation as new generations succeed the old.

7. National forest logging practices have improved considerably in the past decade, and this improvement is expected to continue. This will result in sediment rates substantially lower than those in the past.

Range Management Assumptions

1. The area grazed will decline during the next 50 years because some private rangeland will be developed for housing, particularly near reservoirs and other recreation areas. Also, it is expected that some converted timberlands will be allowed to revert to timber.

2. Grazing practices on much of the area are expected to improve because (a) economics will force ranchers to manage more intensively and inefficient operators will be forced out of ranching by competition, (b) new generations of ranchers with more resource management training will abandon or modify many of the traditional practices that have been detrimental to the land, (c) increasing competition for land will make other uses more profitable on marginal grazing lands, and (d) repeated control burning, which is presently not a problem but could become one of the most destructive influences on soil resources, will be reduced to about 25 percent of present levels.

3. Many areas that have been poorly managed in the past will continue to deteriorate, and sediment yield will continue to accelerate on these lands.

4. Because of the balancing effect of the conditions noted in items 2 and 3, future soil erosion and sediment yield attributable to grazing will slightly increase on privately owned lands. On national forest and other public lands, however, steady improvement is expected.

5. In the national forests, suitable brushfields will be converted to grass for grazing, much of it as part of the fuel-break program. Some similar conversion will also be made on privately owned lands.

Deer Management Assumptions

1. Public opinion essential to deer management is slowly improving and will promote some important changes in management during the next 50 years. However, progress will probably be slow, and this overpopulation of deer is expected to remain a problem for many years.

2. While the remaining old-growth timber is being harvested, deer numbers will increase. Populations will level off when most of the timber resource is placed under sustained-yield management.

Other Assumptions

1. Total populations of the Eel and Mad River Basins will increase slowly during the next 50 years. Most of the increase will occur near the present urban centers and proposed water developments.

2. Urban expansion in the valleys and the use of valleys for reservoirs will force some agricultural activity into the foothills to lands presently being used for timber production and grazing.

3. The creation of the Redwood National Park, the development of reservoirs and the construction of more and better roads will increase outdoor recreation opportunities and use. There will be a substantial increase in the number and scope of summer home and resort developments.

STREAMBANKS

SCS PHOTO 3-5018-7

"Streambank erosion of terrace material on Boulder Creek in the Mad River Basin."

In an average year enough soil is eroded from streambanks in the Eel and Mad River Basins to spread a strip 75 feet wide and one foot deep along U. S. Highway 101 across California from Mexico to Oregon. This gnawing action of water against streambanks causes about 64 percent of the total sediment yield within the basins. For the purpose of this study, streambank erosion is defined as the process whereby material is removed from channel banks by erosive action of the stream and includes landslides smaller than 200 feet, measured along the stream channel.

AVAILABLE DATA

The following material was available for use in determining the sediment yield from streambanks:

1. U. S. Geological Survey Topographic Quadrangles (Scale 1:62,500 and 1:24,000)

2. Aerial Photographs: 1941, 1944, 1948, and 1965 Flights (Approximate scale 1:20,000)

3. Soils information developed by the River Basin Planning Staff.

SURVEY PROCEDURES

Because of the large number of streams and the great variation in sizes, a sampling technique was used in selecting streams to be studied. Streams were classified by order, in accordance with Strahler's modification [1] of Horton's stream ordering system. For this method, standard U. S. Geological Survey topographic quadrangles, scale 1:24,000 are preferred, but were available for only a small portion of the basins, so 1:62,500-scale maps were used as base maps. Only streams delineated by blue lines on the maps were considered, and the uppermost stream reaches were designated second order. First order streams, indicated by V-shaped depressions in contour lines, were included as a phase of studies on sheet and gully erosion. Each order number was continued downstream until a stream was joined by another of the same order. Below the confluence, the stream order was increased one number. An illustration of the stream ordering system is presented on the following page.

Stream orders and lengths vary with the scale of topographic base maps; more channels are shown on 1:24,000-scale maps than are shown on 1:62,500-scale maps. A comparison of stream orders and lengths was made in a part of the Eel River Basin covered by maps of both scales. The total length of channels shown on the 1:24,000-scale maps was double that on the 1:62,500-scale maps, so adjustments were made accordingly over the entire study area.

The number of samples for each stream order was determined in relation to its total length, and specific streams to be sampled were selected from

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1/ Kenneth L. Bowden and James R. Wallis, "Effect of Stream-ordering Technique on Horton's Laws of Drainage Composition." Geol. Soc. America, Bulletin, vol. 75, pp. 767-773 (1964).

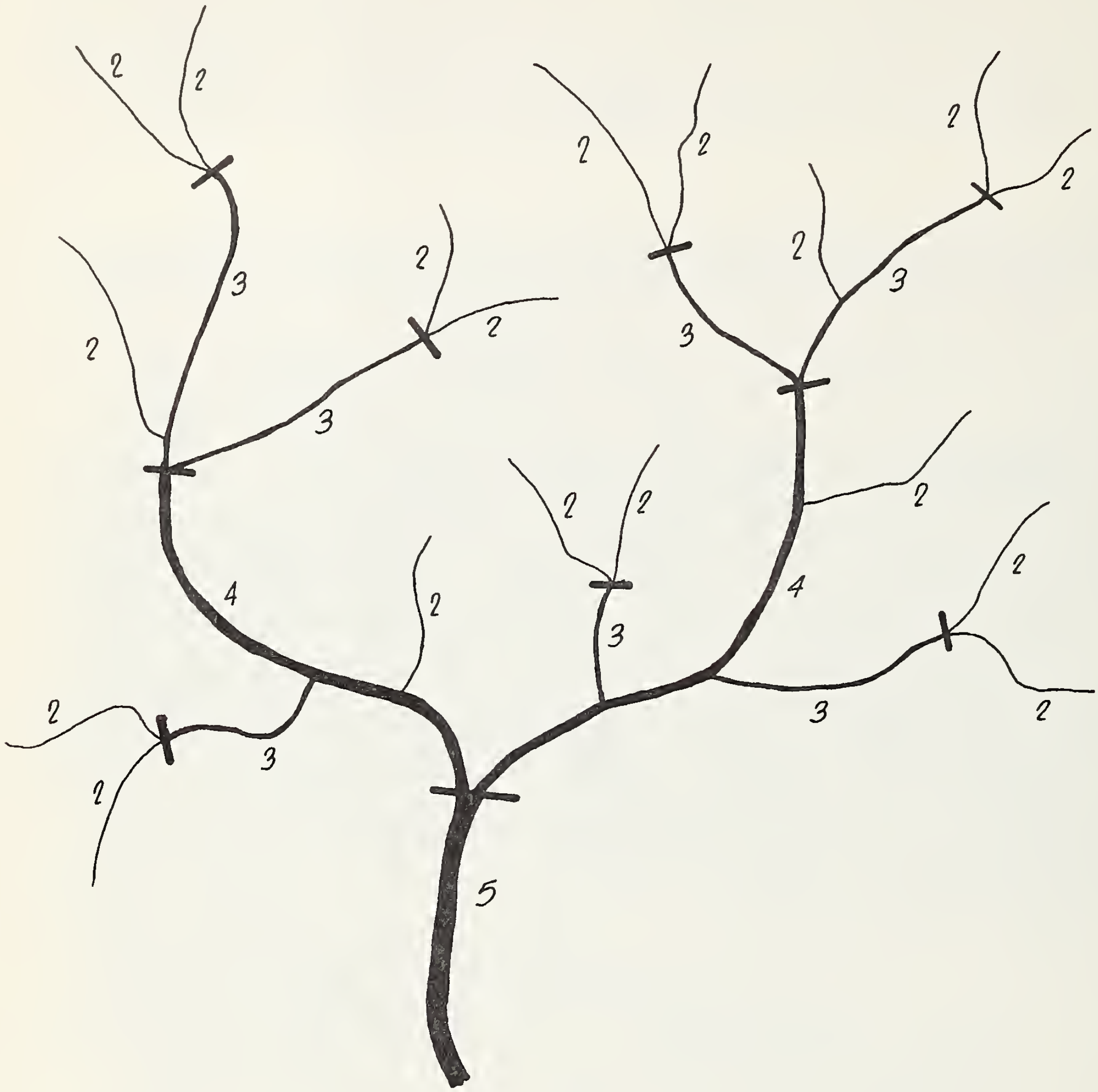

ILLUSTRATION
of
STREAM ORDERING

topographic maps. These sample streams were studied under stereoscope on 1965 aerial photographs and the sample reaches were selected. A relatively unobstructed view of the sample site on the aerial photograph was an important consideration. Sample reaches averaging one mile in length were measured. The stream area in the bottom or at the top of eroded banks, whichever was most visible, was delineated on the aerial photograph and measured by planimeter. An Abrahms height finder was used to determine the average height of eroded banks.

This process was repeated for the corresponding sample reaches on 1941 aerial photographs; where 1941 photographs were not available (about 25 percent of the area), 1944 or 1948 photographs were used. The streambank volume that eroded during the time between aerial flights is the difference in channel area times the average depth of the same reach. The average annual sediment yield was computed for each sample reach.

Of the 10,158 miles of stream in the Eel Basin, about 232 miles, or about 2.3 percent of the total were sampled. For the Mad Basin, about 61 miles of the 2,562 miles of stream were sampled, representing about 2.4 percent of the total. About 50 percent of the samples were checked in the field to assure that they were typical and that the measurements were reasonably accurate. In addition, many stream reaches were observed in the field and compared with the sample reaches.

DATA ANALYSIS

Since there was a possibility that the average annual sediment yield could vary for the three time periods, 1941-65, 1944-1965, and 1948-1965, it was necessary to make a comparison to see if the rates needed adjustment. To make this comparison, average annual suspended sediment rates were computed by expanding U. S. Geological Survey sediment gage data for each of the three periods, as explained in the addendum "Special Sediment Studies." Results of the comparison showed that the rates for the 1944-1965 and the 1948-1965 periods varied only slightly from that for the 1941-1965 period. Therefore, the 1941-1965 study period was used, and no adjustment was made for the other two periods.

For each stream order and unit in the Eel River Basin, both the sample lengths in miles, and the sediment rates of the samples, in acre-feet per year, were totaled. The aggregate sample of sediment rates was divided by the total sample length to arrive at an average sediment rate per mile for each order and unit. The average sediment rate per mile was multiplied by the total length of streams for that order and unit to obtain the final sediment rate in acre-feet per year.

A similar process was used for the Mad River Basin, except that an aggregate sample for each stream order was derived from samples taken from the entire basin. The aggregate sample was used to determine the annual sediment yield rate per mile for each stream order in the basin. This rate was multiplied by the total length of streams in each unit for that order to arrive at the final sediment yield rate in acre-feet per year.

PRESENT SEDIMENT YIELD

The results of the present sediment yield studies for the Eel and Mad River Basins are presented in the tables "Present Annual Sediment Rate by Stream Orders and Units" and "Stream Channel Lengths by Stream Orders and Units" on the following pages. Erosion of streambanks and channels in the various subbasins accounts for 45 to 74 percent of the sediment yield from all sources.

As shown on the tables, the erosion rates per mile for 2nd and 3rd Order streams are a fraction of those for the higher order streams, but their total sediment yield is significant because of their great numbers and total lengths. These smaller streams represent about 70 to 90 percent of the total lengths of all streams. Controlling the erosion in these streams would reduce the sediment yield from streambanks by about 54 percent.

The only 7th Order channel is the 113 miles of the Eel River from Dos Rios to the Pacific Ocean. It yields about 54 percent of the total annual sediment from streambanks in the Main Eel Subbasin and about 29 percent of that in the entire Eel and Mad River Basins. Sediment yield in this reach is high because of erosion of banks, averaging about 35 feet in height, which occur in terrace material and in the steep hillsides of narrow canyons.

The 4th, 5th, and 6th Order streams produce from 2 to 35 percent of the total sediment from streambanks for the various subbasins, and their combined contribution to the Eel and Mad River Basins is 17 percent of the total from streambanks.

The direct and indirect effects of man's activity on sediment yielded from streambanks could not be determined within the scope of this study. While it may be possible to recognize and measure the extent of streambank erosion caused by man at a particular site, it is virtually impossible to measure the effects of that same activity farther downstream, especially in the larger streams. The portion of streambank erosion due to man's activity on the hillsides away from the stream was another problem that could not be investigated within the scope of this study. Reduction of vegetal cover through man's activities, such as logging, road construction, and overgrazing, increases runoff and probably accelerates streambank erosion, especially in the immediate area of the disturbance.

FUTURE SEDIMENT YIELD

Without the installation of a land treatment program, the future sediment yield from streambanks is expected to continue at about the present rate of 9,258 acre-feet per year for the next 50 years. Major storms, such as that of December 1964, leave most of the streambanks bare and subject to heavy erosion for many years. The subsequent regrowth of vegetation along the banks is sometimes retarded by the less intense storms.

Present Annual Sediment Yield From Streambanks By Stream Orders and Units

Unit or Subunit	Drainage Area (Sq. Miles)	Sediment Yield (Acre-feet/Year) Stream Orders 2nd	3rd	4th	5th	6th	7th	Totals
EEL RIVER BASIN								
Outlet Creek--Pillsbury Subbasin								
Lake Pillsbury								
Scott Dam Subunit	287	37	74	7	3	-	-	121
Pressley Subunit	60	44	13	2	-	4	-	63
Outlet Creek	163	29	65	9	4	-	-	107
Willis Ridge								
English Ridge Subunit	142	34	22	21	12	7	-	96
Rodeo Valley Subunit	57	16	15	3	-	43	-	77
Subtotals	709	160	189	42	19	54	-	464
Middle Fork Subbasin								
Wilderness	205	92	35	26	41	-	-	194
Black Butte	162	137	38	14	16	-	-	205
Williams-Thatcher	116	34	28	18	-	18	-	98
Covelo	99	28	36	8	4	-	-	76
Elk Creek	115	166	142	31	10	-	-	349
Dos Rios	56	44	19	4	-	37	-	104
Subtotals	753	501	298	101	71	55	-	1,026
South Fork Subbasin								
Laytonville	125	49	13	3	6	-	-	71
Lake Benbow	413	142	59	34	58	127	-	420
Humboldt-Redwoods	152	105	46	27	-	46	-	224
Subtotals	690	296	118	64	64	173	-	715
Van Duzen Subbasin								
Yager Creek	132	79	57	8	20	4	-	168
Van Duzen River	297	199	93	25	256	12	-	585
Subtotals	429	278	150	33	276	16	-	753
Main Eel Subbasin								
North Fork	283	314	78	6	35	34	-	467
Bell Springs	335	457	319	122	-	-	559	1,457
Sequoia	187	230	68	13	42	-	751	1,104
Larabee Creek	84	134	30	7	-	-	-	171
Lower Eel	214	129	124	23	-	-	1,402	1,678
Eureka Plain	221	80	19	14	6	-	-	119
Subtotals	1,324	1,344	638	185	83	34	2,712	4,996
EEL RIVER BASIN TOTALS	3,905	2,579	1,393	425	513	332	2,712	7,954

Present Annual Sediment Yield From Streambanks By Stream Orders and Units

Unit or Subunit	Drainage Area (Sq. Miles)	Sediment Yield (Acre-feet/Year)						
		Stream Orders						
		2nd	3rd	4th	5th	6th	7th	Totals
MAD RIVER BASIN								
Ruth	143	81	56	8	33	-	-	178
Butler Valley	250	198	49	19	15	100	-	381
North Fork	47	40	8	8	-	-	-	56
Blue Lake	65	61	20	9	-	33	-	123
Mad River Subtotals	505	380	133	44	48	133	-	738
Little River	46	39	9	5	10	-	-	63
Big Lagoon	84	78	18	13	3	-	-	112
Coastal Drainage Subtotals	130	117	27	18	13	-	-	175
Snow Camp	68	57	15	13	-	-	-	85
Beaver	107	70	27	22	7	-	-	126
Orick	119	98	40	10	24	8	-	180
Redwood Creek Subtotals	294	225	82	45	31	8	-	391
MAD RIVER BASIN TOTALS	929	722	242	107	92	141	-	1,304

Stream Channel Lengths By Stream Orders and Units

Unit or Subunit	Stream Channel Lengths (Miles)						
	Stream Orders						
	2nd	3rd	4th	5th	6th	7th	Totals
EEL RIVER BASIN							
Outlet Creek-Pillsbury Subbasin							
Lake Pillsbury							
Scott Dam Subunit	515	190	23	23	-	-	751
Pressley Subunit	100	39	6	-	12	-	157
Outlet Creek	354	155	31	18	-	-	558
Willis Ridge							
English Ridge Subunit	290	81	15	9	18	-	413
Rodeo Valley Subunit	118	23	3	-	18	-	162
Subtotals	1,377	488	78	50	48	-	2,041
Middle Fork Subbasin							
Wilderness	368	131	25	22	-	-	546
Black Butte	302	76	18	14	-	-	410
Williams-Thatcher	189	48	14	-	16	-	267
Covelo	152	65	12	5	-	-	234
Elk Creek	270	85	16	4	-	-	375
Dos Rios	108	26	2	-	15	-	151
Subtotals	1,389	431	87	45	31	-	1,983
South Fork Subbasin							
Laytonville	228	95	25	9	-	-	357
Lake Benbow	712	237	51	42	49	-	1,091
Humboldt-Redwoods	231	56	26	-	24	-	337
Subtotals	1,171	388	102	51	73	-	1,785
Van Duzen Subbasin							
Yager Creek	254	94	23	17	6	-	394
Van Duzen River	541	155	18	65	8	-	787
Subtotals	795	249	41	82	14	-	1,181
Main Eel Subbasin							
North Fork	549	168	34	19	15	-	785
Bell Springs	476	151	34	-	-	43	704
Sequoia	273	75	5	10	-	32	395
Larabee Creek	152	33	19	-	-	-	204
Lower Eel	323	124	22	-	-	38	507
Eureka Plain	398	126	33	16	-	-	573
Subtotals	2,171	677	147	45	15	113	3,168
EEL RIVER BASIN TOTALS	6,903	2,233	455	273	181	113	10,158

Stream Channel Lengths by Stream Orders and Units

Units or Subunits	Stream Channel Lengths (Miles)						
	Stream Orders						
	2nd	3rd	4th	5th	6th	7th	Totals
MAD RIVER BASIN							
Ruth	306	62	15	18	-	-	401
Butler Valley	470	110	21	13	41	-	655
North Fork	96	17	9	-	-	-	122
Blue Lake	144	46	10	-	13	-	213
Mad River Subtotals	1,016	235	55	31	54	-	1,391
Little River	93	21	5	9	-	-	128
Big Lagoon	185	41	14	2	-	-	242
Coastal Drainage Subtotals	278	62	19	11	-	-	370
Snow Camp	136	35	14	-	-	-	185
Beaver	166	61	24	6	-	-	257
Orick	233	90	12	21	3	-	359
Redwood Creek Subtotals	535	186	50	27	3	-	801
MAD RIVER BASIN TOTALS	1,829	483	124	69	57	-	2,562

SCS PHOTO 3-4317-6

"Minor tributary to South Fork Van Duzen River choked with debris."

SCS PHOTO 3-5258-8

"Typical stream bank erosion of terrace material. The tree on the left has been undercut by stream action."

LANDSLIDES

SCS PHOTO 3-4317-10

SCS PHOTO 3-4840-7

"Landslide on Cuneo Creek in Bull Creek Watershed before and after December 1964 flood."

Landslides are prominent features of the landscape in the Eel and Mad River Basins and are the most visible source of sediment yield. Because of this prominence, they are usually cited as the major mode of landscape degradation as well as the major source of sediment in the basins. However, the data indicates that landslides contribute about 25 percent of the total volume of sediment yielded by the watersheds and rank second to streambanks as a source.

TYPES OF LANDSLIDES

In the terminology proposed by the Highway Research Board, the landslides producing most of the sediment in the basins are defined as a combination of slump and earthflow.[1/] In this type of slide, the head, or upper part, of the slide mass slumps downward, and the toe area becomes so churned and broken up that it is very susceptible to stream erosion and is easily carried away during high flows. There have been instances where movement has been very rapid and streams have been dammed by landslides for short periods; generally, however, movement is slow to imperceptible.

Other types of slides encountered in the study include rockfalls and earthflows. Rockfalls usually occur on oversteepened slopes that have been undercut by streams, resulting in high, nearly vertical cliffs. Earthflows are very widespread in the basins and appear on many open hillsides covered by grass or a combination of oak trees and grass. In this report, earthflows are restricted to the weathered mantle. They are generally slow moving, and failure occurs when shearing resistance is decreased by excess moisture. Downslope movement causes the mass to form a bulbous-shaped body at the toe. The land frequently assumes a rumpled appearance, and gullies in various stages of development are evident.

Some slides occur high on hillsides and are not subject to the erosive action of streams. Only a small part of the material from these slides reaches the streams.

The high sediment-producing slides in the basins are a complex combination of slump and earthflow types. Failure is usually not confined to a single zone but is frequently a slide within a slide. The major plane may be more than 100 feet below the surface, and several others may also be present at lesser depths within the main slide. These massive slides, some of which extend for a mile or more up the slope, are often completely covered by earthflows. The areal extent of some of these slides measures in square miles.

Although less important than all other slides in the volume of sediment they produce, debris slides are striking features of the Eel River Basin landscape. They occur along broad northwest-trending belts and are probably evidence of large shear zones. Slump ponds, gullies, and generally rumpled topography are characteristic features as the photograph on the next page illustrates.

1/ Edwin B. Eckel, ed., Landslides and Engineering Practice, Highway Research Board Special Report 29, National Academy of Sciences-National Research Council Publication 544, p. 20 ff. (Washington, 1958).

SCS PHOTO 3-4780-5

"Example of a very large debris slide in the Middle Fork Subbasin. Rumpled topography with large, active gullies is evident, and a small slump pond is visible on the right."

A study on soil creep is currently in progress, and preliminary data were available.[1] Soil creep is defined as the process of gravitational mass movement whereby the soil and weathered mantle flows or creeps slowly downhill at a rate of 1 to 2 centimeters per year. One of the objectives of the soil creep study is to develop basic data on mechanisms and rates of natural soil creep and landslides. Most of the sample sites lie within the Eel River Basin, and data developed by the study will be useful to planners and designers of future projects.

AVAILABLE DATA

Geologic data available at the beginning of the survey consisted of published reports on the geology of specific areas, ground water reports, and broad reconnaissance studies. In general, landslides were mentioned only briefly in the published reports. General geology of the Eel and Mad River Basins is shown on the Ukiah (1960), Redding (1962), and Weed (1964) Sheets of the Geologic Map of California published by the State Division of Mines and Geology.

Landslide data available was scarce and consisted only of a reconnaissance investigation that estimated the amount of material that could slide into proposed reservoirs on the Eel River.[2]

Aerial photographs taken in 1941, 1944, 1948, and 1965 and the latest editions of U. S. Geologic Survey Topographic Quadrangles were used extensively.

SURVEY PROCEDURES

Engineering and geological literature abounds with definitions of landslides, but the consensus seems to define a landslide as the downward movement of slope-forming materials, such as rock and soil. For this study, two criteria had to be met in order that "downward movement of material" could be classified as a landslide: (1) the slide had to be large enough to be visible on a standard 1:20,000-scale aerial photograph and (2) the slide had to be producing sediment.

Many spectacular landslides can be seen from roads that traverse the basins, and many more occur in remote canyons. Because many slides are remote and the basins are large, it was necessary to use aerial photographs. Since all aerial photographs could not be examined, a sampling technique was devised. Depending on the intensity of the sample desired, every fifth,

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1/ Eugene Kojan, Rates and Mechanics of Natural Soil Creep; 1966 Progress Report, pp. 12-34. (Berkeley, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, 1966).

2/ California Resources Agency, Department of Water Resources, North Coastal Area Investigation; Engineering Geology, DWR Bulletin 136. Appendix E, vol. II, pp. 405-410. (Sacramento, August 1965).

tenth, or fifteenth photograph in alternate flight lines was chosen on an aerial photograph index map, and the entire area of each sampled photograph was examined. By examining every tenth photograph in alternate flight lines, about 25 percent of the land can be studied. The sampling intensity used in the study ranged between 22 to 48 percent and averaged 32 percent. Based on experience gained in the Eel River Basin, the intensity was decreased to 22 percent for the Mad River Basin, and considerable time was saved.

The smallest slide that could be adequately studied was found to be 200 feet in one dimension, which appears as a tenth of an inch on aerial photographs with a scale of 1:20,000. Slides smaller than 200 feet in one dimension were included in the studies of sheet and gully, road, and streambank erosion.

The entire sample photo was examined in detail under the stereoscope, and the area of sediment producing slides was measured. Slides falling on the edges of the sample photographs were measured on adjacent photos to minimize errors due to distortion. When a landslide moves, it leaves a voided area that can be seen distinctly and measured on aerial photographs. Since the cross section of the voided area is usually parabolic, it was necessary to determine the average depth of the voided area to compute the volume of material lost to the stream. Initially, the average depth was measured with a height finder, but it was found that it could be estimated. These estimates were checked during field examinations of accessible slides and were found to be reasonably accurate.

Early in the study it was hoped that relative movement of the slower-moving, less spectacular slides could be used as one of the parameters in computing sediment rates. In rare cases such movement can be detected, but this movement could not be measured on small-scale aerial photographs. Many active sediment-producing slides have not slipped into streams in one spectacular splash, but have moved relatively slowly. These exhibit the classical features of active slow-moving slides, such as leaning trees, rumpled and hummocky terrain, slump ponds, and raw embankment exposed at the toe.

Where indicators suggest an active slide, movement of about 200 feet (approximately one-tenth inch on the photograph) can be detected. Where there was no measurable amount of movement, a conservative rate of one foot per year was assumed.[1/] The quantity of sediment yielded by a landslide is

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1/ Eugene Kojan, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley. (October 1967 conversation). Measurements were made on an active slide in Tertiary sediments near Moraga, California; movement ranged from 12 to 18 inches per year.

The Resources Agency of California, Department of Water Resources, Northern District, Upper Eel River Development--Middle Fork Eel River Landslides, Investigation; May 1967 Progress Report, p. 13 ff. (Red Bluff, California, 1967).

strongly influenced by the extent of raw embankment exposed to the eroding forces of the stream, as the photograph following the next two pages illustrates. The rate of movement is multiplied by the cross-sectional area of the exposed or eroding face to give the estimated annual volume of sediment yielded by the slide.

Landslides were located on 1965 aerial photographs, measurements were made, and the volume of material lost to the stream was computed. This procedure was repeated on older photographs covering the same area. Some were measured on 1941 photographs, and others on those taken in 1944 and 1948. The amount of material eroded in the time span between flights is represented by the difference in volume measured on both sets of photographs. Dividing this volume by the number of years between flights gives the estimated annual volume of sediment produced by slides.

Since land loss is computed using the time span between flights, some discrepancies could occur if the various periods did not have similar precipitation, runoff, and suspended sediment yield characteristics. The 1941-65 period was considered as the base period since most of the basin was covered by 1941 photos; it is also the longest time span that is covered by aerial photos. Average annual suspended sediment yield for the gage "Eel River at Scotia" was determined for all three periods--1941-65, 1944-65, and 1948-65. The methodology is described in the addendum "Special Sediment Studies." The yield during the latter two periods was 1 percent lower and 12 percent higher, respectively, than that for the 24-year base period. Since the number of samples that fell in areas covered by 1944 and 1948 aerial photos is relatively small, no adjustments in these data were considered necessary.

Besides volume estimates, other information was recorded for each sample slide. This information included an interpretation of the specific geologic situation, either from field examination or from geologic map and aerial photograph. Probable causes of the slide and possible means of stabilization were also recorded.

A total of 738 individual landslides were examined on aerial photographs. About 10 percent of these were examined in the field to check various estimates made from aerial photographs. Because of the limited time available for the survey, only slides accessible by road were field-checked.

DATA ANALYSIS

The volume of material yielded by slides was tabulated and the area covered by each photo was determined. It was assumed that the portions of each hydrographic unit not examined on aerial photographs were yielding sediment from landslides at about the same rate as the sample areas. The average annual sediment rate per square mile for the sampled part of each unit was determined, and this rate was applied over the entire unit.

PRESENT SEDIMENT YIELD

The results of the present sediment yield studies for landslides in the Eel and Mad Basins are presented in the following table.

Present Sediment Yield From Landslides

Unit or Subunit	Drainage Area (Square Miles)	Present Sediment Yield (Acre-Feet/Year)
EEL RIVER BASIN		
Outlet Creek-Pillsbury Subbasin		
Lake Pillsbury		
Scott Dam Subunit	287	58
Pressley Subunit	60	32
Outlet Creek	163	46
Willis Ridge		
English Ridge Subunit	142	30
Rodeo Valley Subunit	57	22
Subtotal	709	188
Middle Fork Subbasin		
Wilderness	205	176
Black Butte	162	39
Williams-Thatcher	116	5
Covelo	99	24
Elk Creek	115	87
Dos Rios	56	35
Subtotal	753	366

Present Sediment Yield From Landslides

Unit or Subunit	Drainage Area (Square Miles)	Present Sediment Yield (Acre-Feet/Year)
EEL RIVER BASIN (Continued)		
South Fork Subbasin		
Laytonville	125	2
Lake Benbow	413	460
Humboldt-Redwoods	152	159
Subtotal	690	621
Van Duzen Subbasin		
Yager Creek	132	255
Van Duzen River	297	219
Subtotal	429	474
Main Eel Subbasin		
North Fork	283	70
Bell Springs	335	707
Sequoia	187	431
Larabee Creek	84	123
Lower Eel	214	181
Eureka Plain	221	5
Subtotal	1,324	1,517
EEL RIVER BASIN TOTAL	3,905	3,166
MAD RIVER BASIN		
Ruth	143	10
Butler Valley	250	211
North Fork	47	38
Blue Lake	65	Trace
Subtotal (Mad River)	505	259
Little River	46	2
Big Lagoon	84	14
Subtotal (Coastal Drainages)	130	16
Snow Camp	68	56
Beaver	107	79
Orick	119	39
Subtotal (Redwood Creek)	294	174
MAD RIVER BASIN TOTAL	929	449

SCS PHOTO 3-4845-3

Downstream view along Yager Creek, a tributary of the Van Duzen River. The toe of an active landslide can be seen along the left side of the canyon. During high flows, the erosive forces of the stream can act on the entire 900 foot toe of the slide. The slide extends about 2,800 feet up the canyon wall and contains about 6.8 million cubic yards of material.

The relatively low sediment rate from landslides for the Outlet Creek-Pillsbury Subbasin could be caused by several factors. Differences in geology may have some effect but are difficult to assess because of the generalized nature of published geologic maps. The most obvious relationships are those between sediment rate and runoff. Sediment yields are generally high in those units with the highest rainfall and runoff. In the Outlet Creek-Pillsbury Subbasin, rainfall, runoff, and sediment yield are lower than in the other subbasins.

Higher-than-normal sediment yields from landslides and streambank erosion are found in the Main Eel Subbasin. These yields probably result from the rugged topography and abnormally narrow canyons in the lower reaches of the Eel River. Generally, relief becomes more gentle and canyons widen in a downstream direction in most drainage basins; however, the opposite is true of the Eel River Basin, and as a result, large volumes of water are forced through narrow canyons during major storms, causing streambank erosion and landslides.

Nearly all landslides take place under the influence of geologic, topographic, and climatic conditions that are common to large areas. These conditions are about equally important in the formation of landslides. Man's activities, such as some land use practices are also important, and the most influential land use practices probably are logging, road building, and vegetal cover conversion.

Conditions that cause landslides can be placed into two main categories: (1) those that contribute to high shear stress by unbalancing the stable slopes, such as the removal of toes of slopes by stream action, and (2) those that contribute to low shear strength in the bedrock mass, such as faults, joints, and cleavage. Since slides are caused by a combination of conditions, it is difficult to pinpoint a specific cause of a landslide. While removing the toe of a slope by stream erosion or road construction may appear to be the most evident cause of a specific landslide, it may be only the last link in a chain of events leading to the failure of the slope.

From the watershed management point of view, the identification of landslides by cause is a useful and necessary assessment, even though judgment errors are bound to occur. Assuming that slopes in the basins are now in a delicate state of equilibrium, any condition that causes the slope to fail can be considered the primary cause of a slide, or the triggering device. Without the triggering device, the slope would probably remain stable for an indeterminable period. The apparent primary causes of landslides were determined from aerial photographs and were verified for those slides that were checked in the field.

In general, primary causes of landslides can be grouped into two categories--those associated with man's activities and those associated with natural geologic erosion. Roads and logging operations are easily detected on aerial photographs, and when these operations caused a slide, it was noted. From an aerial photograph, it is nearly impossible to determine if a slide is caused by overgrazing. However, compared with more evident causes of slides, such as streambank erosion, logging, and road building, overgrazing is believed to have little influence in creating new landslides in the

basins. Causes were segregated during the study, and it appears that of the sediment yield attributed to landslides, 16 percent originated from slides that were influenced by man's activities.

FUTURE SEDIMENT YIELD

If a land treatment program is not installed, the future sediment yield from landslides will probably increase from 3,615 to 4,500 acre-feet yield per year by the year 2020. This increase is based on the assumption that man will make more intensive use of the basins in the future.

OTHER STUDIES ON LANDSLIDE PROBLEMS

As an aid to planners, this section summarizes some of the previous studies made on landslides by other agencies and professional societies.

The Association of Engineering Geologists has assembled a map showing the distribution of known landslides over 100 feet in the largest dimension in Ventura, Los Angeles, and San Diego Counties. This information alerts planners, such as road builders and developers, to potential problem areas.[1/]

The California Department of Water Resources is conducting a detailed study on landslides around the perimeter of the proposed Dos Rios Reservoir in the Middle Fork Eel River Subbasin. The Bureau of Reclamation is making a similar study of all landslides around the perimeter of the proposed English Ridge Reservoir in the Outlet Creek-Pillsbury Subbasin.

The Pacific Southwest Forest and Range Experiment Station, U. S. Forest Service, is studying mass erosion processes in the North Coastal area. Another study has been completed on the Caspar Creek experimental forest south of Fort Bragg, in which present and potentially unstable areas have been mapped. Logging and roadbuilding activities are being planned to avoid these areas.

Landslides and potentially unstable areas in Nicasio Valley in Marin County are also being mapped by the Experiment Station to provide the County Planning Commission with information about the distribution of landslide zones and other geologic hazards. The information will be used by the Planning Commission in zoning Nicasio Valley for residential and commercial development. It should lead to better zoning, decrease the hazard of landslides in the development, and reduce the sediment load to streams.

Agencies concerned with water development in the basins will probably make similar studies on landslide problems and geologic hazards connected with future projects. There is also a need for a comprehensive and detailed mapping of active and potential landslide areas for use by land managers and developers.

1/ F. B. Leighton, "Preliminary Map Showing Landslide Locations in a portion of Southern California," in Engineering Geology in Southern California, Richard Lung and Richard Proctor, eds., pp. 194-207. (Los Angeles, Association of Engineering Geologists, 1966).

SCS PHOTO 3-4566-2

"Erosion of road gutter and roadbank, Middle Fork Subbasin."

Sediment yield from roads is defined as that directly caused by road construction and maintenance and includes landslides within the road prism that are smaller than 200 feet in one dimension. Occasionally road fills encroached upon streams and accelerated streambank erosion, but it was often difficult to determine the amount of sediment yield that should be charged to each source. In these instances, the sediment yield was included in the study of streambanks or landslides.

Annual sediment yield from roads was about 1/2 of one percent of the total, or 72 of the 14,345 acre-feet per year from all sources. Although roads yielded only a relatively small amount of the total sediment, the sediment rate per unit area of road was quite high. If that portion of sediment from landslides and streambank erosion caused by road construction were included under road erosion, it is possible that as much as 3 percent of the sediment in the basins might be attributed to roads.

AVAILABLE DATA

The sources of data used in this part of the study were the following:

1. USDI Geologic Survey, Topographic Quadrangles (Scale 1:62,500). (Washington, D. C., latest available editions).

2. USDA Forest Service, "Development Transportation Plan Maps" (Scale: 2 inches = 1 mile) (San Francisco, latest available editions).

3. USDA Forest Service, Manuals: Title 7700 and Title 5600. (Washington, U. S. Government Printing Office).

SURVEY PROCEDURES

Only roads shown on USGS Topographic Quadrangles (Scale 1:62,500) and roads in national forests shown on Forest Service Development Transportation Plan Maps were included in this study. Erosion from temporary roads, skid trails, landings, and other roads not shown on the maps was considered as a phase of the studies on sheet and gully erosion.

Since road erosion studies were made on a sampling basis and the amount of erosion was variable, it was necessary to classify roads into categories for data analysis. For this study, it was convenient to use the classification shown on the USGS Topographic Quadrangles: heavy-duty, medium-duty, light-duty, and unimproved roads. In general, heavy-duty roads are four-lane, paved highways, and medium-duty roads are two-lane, paved highways. Most of the U. S. and State highways fall into one of these two categories. Light-duty roads are usually two-lane with some type of surfacing and are generally secondary or county roads. Umimproved roads are usually one- or two-lane and unsurfaced, and those on private land are generally not open to the public. Although the Forest Service has a different classification system for roads in the national forests, these roads were classified into the above categories for data analysis. Earlier in the study, the type of road surface was recorded, but the amount of surface erosion was found to be negligible on all types of road surfaces and the classification was abandoned.

Sediment yield was estimated for a ten-year period. The lengths of cutbanks, fills, and sample reaches were measured with a car odometer, and average cutbank and fill heights were estimated. Indicators used as a basis for estimating erosion were the size and number of rills and gullies on cutbanks, fills, and road surfaces; the extent that toes had moved back from the edges of roads and ditches; and the length of roots extending from the banks. The eroded volume of slides and washouts was also estimated. The extent of gully erosion was measured in a few cases, but was generally estimated. The portion of eroded material reaching streams was estimated on the basis of the proximity of the eroded area to waterways and the amount of impediment provided by vegetal cover. Sediment yields were computed and totaled for each sample reach of road, and the pertinent data were recorded on forms developed for this purpose.

The percentage of roads sampled in the Eel River Basin varied according to road classifications: 90 percent of heavy-duty roads, 55 percent of medium-duty, 60 percent of light-duty, and 20 percent of unimproved roads. Because of experience with heavy-duty roads in the Eel River Basin and their low sediment yield, no samples of this road classification were taken in the Mad River Basin, although about half of these roads were inspected. Approximately 15 percent of medium- and light-duty roads and 3 percent of the unimproved roads were sampled.

DATA ANALYSIS

From the sample data collected for each of the road classifications, the aggregate total of annual sediment rates and the lengths of sample reaches were determined. The weighted average annual sediment rate in acre-feet per year per mile of road was computed and was multiplied by the total length of roads in each unit to arrive at the annual sediment yield for that road classification and unit.

Statistical analyses were made on the various sediment yield samples for roads to determine if there was a correlation between the sediment rate and the physical characteristics of the roads, such as land slope and road surface and gradient. Soil types could not be analyzed as a factor because of inadequate information. The analyses showed that there were no significant correlations, indicating that no characteristic can be identified as the most important cause of road erosion.

PRESENT SEDIMENT YIELD

Road lengths and present annual sediment yields in the basins are presented by unit and road classification in the tables on the following pages.

Road Lengths (Miles) by Road Classifications and Units for the Eel River Basin

Unit or Subunit	Heavy Duty	Medium Duty	Light Duty	Unimproved	Totals
	Road Classification				
Outlet Creek-Pillsbury Subbasin					
Lake Pillsbury					
Scott Dam Subunit	-	45	164	220	429
Pressley Subunit	-	12	45	19	76
Outlet Creek	13	18	61	87	179
Willis Ridge					
English Ridge Subunit	-	-	32	87	119
Rodeo Valley Subunit	-	-	9	6	15
Subtotals	13	75	311	419	818
Middle Fork Subbasin					
Wilderness	-	32	20	-	52
Black Butte	-	46	54	62	162
Williams-Thatcher	-	-	7	82	89
Covelo	-	-	45	55	100
Elk Creek	-	-	7	50	57
Dos Rios	-	-	16	32	48
Subtotals	-	78	149	281	508
South Fork Subbasin					
Laytonville	-	12	40	68	120
Lake Benbow	-	61	54	126	241
Humboldt-Redwoods	-	21	40	61	122
Subtotals	-	94	134	255	483
Van Duzen Subbasin					
Yager Creek	-	-	66	31	97
Van Duzen River	-	47	112	102	261
Subtotals	-	47	178	133	358
Main Eel Subbasin					
North Fork	-	-	37	80	117
Bell Springs	-	-	50	96	146
Sequoia	-	-	61	80	141
Larabee Creek	-	-	24	25	49
Lower Eel	14	28	128	45	215
Eureka Plain	23	46	84	39	192
Subtotals	37	74	384	365	860
EEL RIVER BASIN TOTALS	50	368	1,156	1,453	3,027

Present Annual Sediment Yield (Acre-Feet per Year) by Road Classifications and Units for the Eel River Basin

Unit or Subunit	Road Classification: Heavy Duty	Medium Duty	Light Duty	Unimproved	Totals
Outlet Creek-Pillsbury Subbasin					
Lake Pillsbury					
Scott Dam Subunit	-	1	3	1	5
Pressley Subunit	-	1	2	Trace	3
Outlet Creek	Trace	Trace	1	4	5
Willis Ridge					
English Ridge Subunit	-	-	1	5	6
Rodeo Valley Subunit	-	-	Trace	Trace	Trace
Subtotals	Trace	2	7	10	19
Middle Fork Subbasin					
Wilderness	-	1	1	-	2
Black Butte	-	1	1	1	3
Williams-Thatcher	-	-	1	1	2
Covelo	-	-	1	4	5
Elk Creek	-	-	1	1	2
Dos Rios	-	-	1	1	2
Subtotals	-	2	6	8	16
South Fork Subbasin					
Laytonville	-	Trace	2	1	3
Lake Benbow	-	4	2	3	9
Humboldt-Redwoods	-	Trace	1	2	3
Subtotals	-	4	5	6	15
Van Duzen Subbasin					
Yager Creek	-	-	1	Trace	1
Van Duzen River	-	2	2	1	5
Subtotals	-	2	3	1	6
Main Eel Subbasin					
North Fork	-	-	1	1	2
Bell Springs	-	-	2	1	3
Sequoia	-	-	2	1	3
Larabee Creek	-	-	1	Trace	1
Lower Eel	Trace	Trace	1	1	2
Eureka Plain	-	Trace	Trace	-	Trace
Subtotals	Trace	Trace	7	4	11
EEL RIVER BASIN TOTALS	Trace	10	28	29	67

Road Lengths (Miles) by Classifications and
Units for the Mad River Basin

Unit	Road Classification: Heavy Duty	Medium Duty	Light Duty	Unimproved	Totals
Ruth	-	9	50	44	103
Butler Valley	-	-	81	89	170
North Fork	-	8	8	16	32
Blue Lake	7	9	50	17	83
Mad River Subtotals	7	26	189	166	388
Little River	2	-	11	9	22
Big Lagoon	18	-	25	30	73
Coastal Drainage Subtotals	20	-	36	39	95
Snow Camp	-	2	11	28	41
Beaver	-	7	39	29	75
Orick	17	3	41	34	95
Redwood Creek Subtotals	17	12	91	91	211
MAD RIVER BASIN TOTALS	44	38	316	296	694

Present Annual Sediment Yield (Acre-Feet per Year) by Road
Classifications and Units for the Mad River Basin

Unit	Road Classification: Heavy Duty	Medium Duty	Light Duty	Unimproved	Totals
Ruth	-	Trace	1	1	2
Butler Valley	-	-	1	1	2
North Fork	-	-	Trace	Trace	Trace
Blue Lake	-	-	Trace	Trace	Trace
Mad River Subtotals	-	Trace	2	2	4
Little River	-	-	Trace	Trace	Trace
Big Lagoon	-	-	Trace	Trace	Trace
Coastal Drainage Subtotals	-	-	Trace	Trace	Trace
Snow Camp	-	-	Trace	Trace	Trace
Beaver	-	Trace	Trace	1	1
Orick	-	-	Trace	Trace	Trace
Redwood Creek Subtotals	-	Trace	Trace	1	1
MAD RIVER BASIN TOTALS	-	Trace	2	3	5

Major highways (heavy-duty roads) in the basins are usually well planned and maintained and are often located on level terrain. The sediment rate from these roads is only five percent of that from other road classifications. Roads in the other three classes are generally located in mountainous or sloping terrain and are usually not as well planned as the major highways. Sediment yield from unimproved roads is slightly less than that from medium- and light-duty roads, probably because of narrower road widths and smaller areas of cuts and fills. Average annual sediment rates per mile for both basins are 0.001, 0.024, 0.020, and 0.019 acre-feet per year per road mile for heavy-duty, medium-duty, light-duty, and unimproved roads, respectively.

FUTURE SEDIMENT YIELD

Without a land treatment program, the future sediment yield from roads in the next 50 years should increase to twice the present yield, or to 144 acre-feet per square mile. This prediction is based on two assumptions: (1) the number of roads in the basins will more than double by the year 2020, and (2) planning, construction, and maintenance on the future roads will not improve significantly during this period.

POTENTIAL LAND TREATMENT PROGRAM

The land treatment program is discussed in two phases -- remedial measures to alleviate existing erosion problems and management guidelines to prevent future problems. Many remedial measures are not recommended because costs per unit of sediment reduced are usually prohibitive, and in some cases, if watersheds are given proper management, the problems will cure themselves in time. Therefore, emphasis has been placed upon management guidelines designed to solve present problems and to prevent similar ones from developing in the future.

This program was designed for privately owned land and national forests. Some of the management guidelines may be applicable on public lands other than national forests.

REMEDIAL MEASURES

A set of remedial measures that would remedy erosion problems and reduce sediment yields was formulated for each sediment source. All of these measures are presented in this section although many of them are not considered feasible for installation because of excessive costs. The recommended remedial measures are presented in the chapter "Recommended Program."

SHEET AND GULLY EROSION

Remedial measures for sheet and gully erosion are considered practical only for the privately owned grassland portion.

Privately Owned Grassland

In the Eel and Mad River Basins, privately owned grassland comprises 762 square miles, or about 16 percent of the total area. Of this, 562 square miles is natural grassland and 200 square miles is timberland converted to grass for grazing.

Land treatment measures for grasslands will provide the necessary increase in ground cover density and organic litter for watershed protection and forage improvement, but changes in livestock management will be necessary to maintain this condition. On-site investigations will be required to select the most effective treatment for each area. Uniform distribution of livestock is needed to relieve the grazing pressure on high-erosion-hazard lands.

Natural Grassland

To facilitate discussion of problems and treatments, the 562 square miles of natural grassland was grouped into the three erosion classes--slight, moderate, and severe--previously discussed in the section "Data Analysis, Sheet and Gully Erosion" of the chapter "Sediment Yield Studies and Survey Procedures."

"Grassland that has sufficient vegetal cover to prevent excessive erosion. Sediment production is low." SCS PHOTO 3-4657-9

"Grassland that is producing a moderate amount of sediment. There is inadequate vegetal cover to prevent sheet erosion, and there are a few active gullies." SCS PHOTO 3-4840-14

"Grassland that is producing a high amount of sediment. There are many active gullies." SCS PHOTO 3-5210-1

Slight Erosion Class

This class comprises 376 square miles of natural grassland and has low sediment rates that average 58 acre-feet per year. This class was further classified into the following range site categories:

Range Site	Soil Association	Area (Square Miles)
Upland Claypans, Steep Phase	Yorkville association, 15 to 50 percent slopes	65
Loamy	Laughlin association 0 to 30 percent slopes	104
Loamy, Steep Phase	Laughlin association 30 to 50 percent slopes	202
Loamy, Very Steep Phase	Laughlin association 50 to 75 percent slopes	5

The present stocking rate is generally greater than this land can continue to support. Seed is plentiful and ground cover is generally adequate, but the composition and vigor of stands do not provide optimum forage production. Although sediment rates per acre are low, these areas are extensive and therefore constitute a significant source of sediment. They offer opportunity for treatment that will decrease sediment yield, increase forage production, and relieve grazing pressure on lands in the moderate and severe erosion classes.

It is recommended that technical assistance be made available to livestock managers to improve grazing and grassland management on the 376 square miles. In addition, seeding and fertilizing are recommended on 267 square miles of Upland Claypans, Steep Phase and Loamy, Steep Phase range sites, and fertilizing is recommended on 104 square miles of Loamy range site.

Moderate Erosion Class

This class comprises about 149 square miles of natural grassland and has moderate sediment rates that average 94 acre-feet per year. The range sites and the areas are as follows:

Range Site	Area (Square Miles)
Upland Claypans, Steep Eroded Phase	73
Loamy, Eroded Phase	4
Loamy, Steep, Eroded Phase	68
Loamy, Very Steep, Eroded Phase	4

These areas are generally overstocked and have poor ground cover. Strong measures should be taken to bring livestock numbers into balance with forage supply to improve production and to increase the amount of vegetation left for watershed protection.

It is recommended that improved grazing and grassland management be established on the 149 square miles and that, in addition, the 4 square miles of Loamy, Eroded Phase range site be seeded and fertilized. Because of the erosion, intensive remedial measures are not considered possible on the rest of the land in this class.

Severe Erosion Class

This class comprises about 37 square miles of natural grassland and has high sediment rates that average 81 acre-feet per year.

Because plant cover is depleted and bare soil is prevalent, all of the existing vegetation is needed for watershed protection. Fencing to exclude domestic livestock from these areas and the application of fertilizer are recommended to restore protective vegetal cover. Seeding would be desirable, but the gullies and steep slopes make mechanical planting methods generally impractical. Without proper seedbed preparation, seeding would not be effective and is therefore not recommended. Treated areas would be slow to recover, and grazing activity could offset gains in ground cover accomplished by treatment; therefore, permanent exclusion of domestic livestock is recommended for the 100-year period.

Technical guidance will be needed in the selection of areas to be fenced for permanent livestock exclusion. Tree and shrub plants may be recommended as vegetal barriers to reduce runoff, check erosion, and heal the gullies. The grazing capacity lost by livestock exclusion would be replaced by the increased production gained by installation of the remedial measures on other grassland areas.

Converted Timberland

Approximately 200 square miles have been converted from forest or woodland to grass for grazing. The slight, moderate, and severe erosion classes, respectively, comprise about 158, 35, and 7 square miles of these converted areas. In general, this land has higher sediment rates per square mile than natural grassland, and soil loss is accelerating.

Converted timberland soils generally produce less forage than natural grassland soils. The timber soils are usually strongly acid and have a relatively low fertility level for forage plants.[1/] In addition, much effort is required to prevent the regrowth of woody vegetation. While grassland areas

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1/ Robert A. Gardner et.al., Wildland Soils and Associated Vegetation of Mendocino County, California, p. 19ff. (Sacramento: Resource Agency of California, Cooperative Soil-Vegetation Survey Project, 1964).

converted from timberland may bring a more immediate return to the landowner, good quality timberland will yield more returns from timber products over a long period of time.[1]

The recommended land treatment measures take into account the inherent productivity of the soils for timber and forage, the relatively high sediment rates, and the economic benefits.

Converted timberlands were classified into the Douglas-fir timber site classes of the soil-vegetation survey.[2] The following table presents typical soil associations and related depths for the timber site classes:

Timber Site Class	Soil Association	Soil Depth (Feet)
II	Larabee	4+
	Hugo-Josephine	4+
III	Larabee	3 - 4
	Hugo-Josephine	3 - 4
IV	Hugo-Josephine	2 - 3
V	Los Gatos	2 - 3
	Tyson	2 - 3

Slight Erosion Class

This class comprises about 158 square miles and has low sediment rates that average 36 acre-feet per year. On the 120 square miles classified as high (site III) or very high quality for Douglas-fir (site II), grazing should be discontinued and the area reforested. The remaining 38 square miles are not as well suited to timber production and could be left in grassland. Management to increase grass production and decrease sediment yield is recommended for treatment of areas in timber sites IV and V.

Moderate Erosion Class

This class comprises 35 square miles and has sediment rates that average 35 acre-feet per year. Since the land is generally classified as medium

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1/ Adon Poli and E. V. Roberts, Economics of the Utilization of Commercial Timberland on Livestock Ranches in Northwestern California, Miscellaneous Paper No. 25, p. 36ff. (Berkeley, USDA Forest Service California Forest and Range Experiment Station, April 1958).

2/ Robert A. Gardner and others, in the work previously cited, pp. 68-69.

"Converted Timberland."

FOREST SERVICE PHOTOS

(site IV) or low quality for Douglas-fir (site V), reforestation is not recommended. Although no land treatment measures are recommended for these grasslands, proper grazing management is essential to maintain forage production and reduce sediment yield.

Severe Erosion Class

Seven square miles of severely eroded soils are included in the areas of converted timberland. The problems associated with these damaged lands are similar to those encountered on natural grasslands. Permanent livestock exclusion and fertilization is recommended to improve the vegetal cover and thereby reduce sediment yield.

Cost

The total cost of installing remedial measures on privately owned grasslands would be more than $15 million.

STREAMBANKS

Two types of streambank stabilization were considered -- crib dams and rock riprap bank protection. Crib dams were determined to be cheaper than rock riprap and were selected as the most feasible measure for a basinwide remedial program. Detailed studies might show that some other type of construction might be better adapted to solve localized problems.

The type of crib dams investigated was similar to those installed in the Los Angeles River Basin by the Los Angeles County Flood Control District and the Forest Service. These dams are drop structures that are used to stabilize the channel bottom and to reduce the stream gradient and velocity. Lower velocities permit a better rehabilitation of the vegetal cover on streambanks. To prevent serious disruption of fish migration, the effective height of these structures should be limited to three feet.

A preliminary analysis showed that a basinwide program of installation would cost several billion dollars.

LANDSLIDES

The investigation of possible remedial measures was centered on two types of construction -- prefabricated concrete crib restraining structures and a combination of rock riprap and horizontal drains. The concrete crib structures would be constructed so as to stabilize toes and to reduce removal by stream action. Rock riprap along the eroded face at the toes of landslides would protect against stream erosion and, in combination with horizontal drains, would increase the stability of the landslides. Cursory analysis suggests that crib structures, although more expensive, would be more effective than the rock riprap and horizontal drains.

The crib restraining structures closely resemble the crib dams described in the section "Streambanks." Design criteria required that the base width of the structure be equal to the height and that the constructed slope above the structure be 1-1/2:1 or flatter. Provisions to carry surface

drainage away from the slide and the need for horizontal drains were also considered.

The following criteria were considered for a stabilization program using riprap and horizontal drains:

1. The eroding face, normally ranging from 10 to 40 feet vertically, would have a maximum slope after construction of 1-1/2:1.

2. The constructed slope would be protected by rock riprap to prevent undercutting by the erosive action of the stream.

3. Surface drainage would be provided to direct surface runoff away from the slide mass.

4. Horizontal drains would be installed for subsurface drainage.

Interviews with representatives of local drilling companies and the California Division of Highways showed that for planning purposes, spacing of horizontal drains at 20-foot intervals is common practice, but closer spacing is required when large amounts of excess water are encountered.

No remedial measures were planned for landslides occurring on 6th and 7th Order streams in the Eel River Basin or on 5th and 6th Order streams in the Mad River Basin. Landslides on these streams were excluded because they are located within proposed reservoir areas where they would be covered by water, because present conditions will be changed by reservoir operations, or because the hazard of sliding would be reduced by controlled downstream releases. No analyses were made of landslides that may occur within the proposed reservoirs; it is assumed that these studies will be undertaken by the agencies responsible for individual projects.

The total installation costs were estimated to be $287 million for the rock riprap and horizontal drain alternative and $488 million for the crib restraining structures.

ROADS

The types and quantities of remedial measures needed to control erosion on existing roads were estimated in the field concurrently with the sediment studies. Determination of remedial needs was made by noting deficiencies in construction and maintenance procedures used on roads and by making field estimates of corrective work needed.

The following procedures are typical of those needed to remedy the deficiencies:

1. Install culverts, bridges, or grade dips at all natural drainageways and provide adequate inlet and outlet structures.

2. Extend culvert outlets to the toe of road fills, and construct rock plunge pools at culvert outlets where erosion is occurring.

3. Vegetate unstable channels below culvert outlets for a minimum distance of about 100 feet. Shape channels and install jute netting on the sides and bottom. Seed and fertilize at recommended rates.

4. Outslope unsurfaced roads wherever surface drainage problems exist and vegetal and soil conditions provide adequate protection for sheet flows. Inslope and provide road ditches where the vegetal protection is inadequate for sheet flows. Install culverts under roads at regular intervals to drain road ditches.

5. Pave or otherwise stabilize road gutters where erosion is occurring and installation of culverts at regular intervals is impractical.

6. Install horizontal drains, crib walls, or other retaining structures where landslides or unstable soils are a major problem.

7. Construct rock-lined or other hard-surfaced dips in unsurfaced roads where channels carry heavy debris loads or are too shallow for adequate culverts with appropriate inlet conditions.

The following changes in road maintenance procedures are recommended:

1. Avoid removing toes of cutbanks during road smoothing and ditch cleaning operations.

2. Remove excess soil from cleanup and maintenance operations to appropriate waste areas and protect it from erosion.

The estimated cost for a basinwide installation of remedial measures on roads is about $3 million. The following tabulation shows the estimated cost per mile for each road classification in the basins:

Road Classification	Cost per Mile (Dollars) Eel Basin	Mad Basin
Heavy Duty	0	0
Medium Duty	2,330	1,110
Light Duty	830	630
Unimproved	760	290

MANAGEMENT GUIDELINES

These management guidelines are designed to improve existing conditions and to prevent future problems. In some cases, they must be used in conjunction with remedial measures to achieve full rehabilitation of deteriorated sites. However, proper management, by itself, usually has beneficial effects and often can be practiced without great cost to the landowner. In fact, greater long-range financial returns usually result from proper management, with a subsequent stabilization of local enconomies.

The following management guidelines are recommended for the Eel and Mad River Basins.

SHEET AND GULLY EROSION

Logging Guidelines

1. Logging operations should be planned well in advance, as is now done by large timberland owners with a forestry staff. Private owners of small timber tracts should obtain the assistance of foresters to arrive at the best plan for specific areas. In many cases, this would result in better timber prices, more accurate scaling, and protection of soil resources and would leave a healthier stand of timber for future harvests.

2. A system for judging the potential for soil erosion and sediment yield from lands where timber is to be harvested should be used. The Erosion Hazard Rating System used by the Forest Service is a good example. In this system, weighted values are assigned to the individual characteristics of soil, slope, climate, and cover (vegetal and ground cover that is expected to remain after logging). The result is a numerical rating that indicates erosion hazard and recommends the systems to use when harvesting timber for each particular hazard area. It also indicates precautions that should be taken during logging and provides a guide to the type of postlogging treatment needed.

3. Logging systems that minimize soil disturbance should be used. Tractor logging is acceptable in areas of low and moderate erosion hazard. Where it is used the number of skid trails should be minimized, and they should be constructed as nearly parallel to the contour as possible and provided with cross drains after use. Long, continuous downslope skid trails should be avoided because they tend to channel the runoff and form gullies.

   Cable logging or skyline systems are preferred for erosion control and are the only methods recommended for areas of high erosion hazard.

4. Timber harvest should be deferred on extremely unstable soils where logging by today's methods is likely to cause landslides. New methods, which are now being developed, will probably make it feasible to harvest such timber in the future.

5. Landings, roads, and skid trails should be located to avoid creekbeds or washes. Landings should be located on benches away from channels and stream crossings should be avoided wherever possible.

6. When logging near streams, trees should be felled uphill away from channels,and slash and debris should be kept out of watercourses. Any debris inadvertently deposited in channels should be removed immediately, with the least possible disturbance to streambeds and streambanks. To maintain stability of the streambanks, unmerchantable timber and other vegetation growing within about 50 feet of streams should not be disturbed. Burning or mechanical treatment should not be applied in this zone.

7. Steep slopes or shallow areas where sediment will enter directly into streams should not be logged.

8. Temporary bridges or culverts should be installed at all watercourses to be crossed by trucks and tractors. Immediately after logging is completed on a given area, the culverts and all fill material should be removed with a minimum of disturbance to the stream channel.

9. Crossdrains (also referred to as waterbars, water breaks, or dips) should be constructed in all temporary roads and skid trails immediately after logging is completed on a given area and should be reinstalled as necessary. They should have proper outlets and be deep so that they will withstand abuse, including travel over them by tractors or 4-wheel-drive equipment. Recommended spacing for crossdrains on national forest land is determined by the Erosion Hazard Rating. Where the Erosion Hazard Rating is not used, the following spacings are recommended as a rule of thumb:

Percent Gradient	Spacing between Crossdrains (feet)
1 - 6	300
7 - 9	200
10 - 14	150
15 - 20	90
21 - 40	50
Over 41	25

The above spacings are to be measured on the slope and should be considered as a guide only. The water should discharge into areas well protected by rocky ground, slash, or vegetal cover. Crossdrains should be located to promptly intercept runoff from lateral skid trails or other features that may result in concentrating runoff.

10. Landings and skid trails should be seeded with appropriate species immediately after logging is completed, depending upon the erosion hazard.

11. In all areas where an inadequate seed source remains after logging, tree species should be seeded or planted to assure immediate and complete reforestation.

12. Unsurfaced roads should be closed during wet weather.

13. A detailed study should be made to determine the most practical and economically feasible system of deferred harvesting in streamside strips. From the study, specific guidelines should be formulated. The system should be designed to (1) reduce the chance of triggering landslides on logged areas from streambank erosion by maintaining maximum vegetal cover on the toe of slope until the logged area is stabilized, (2) provide a filtering effect by preserving natural litter accumulation to trap sediment coming from the logged area, and (3) provide an adequate buffer zone to aid in keeping logging debris out of stream channels. Protection of fishery habitat by this system is a significant secondary benefit. Width of the stream protection strip should depend on topographic conditions and the density of vegetation. In most cases a distance of about merchantable tree height would accomplish watershed protection objectives and yet allow the later removal of timber with a minimum disturbance of litter, soil, and riparian vegetation within the strip.

    If a skyline system is used, deferred cutting within stream protection strips is unnecessary since such systems keep disturbance of ground and nonmerchantable vegetal cover to a minimum.

    The projected soil erosion rate is based on the assumption that a feasible system can be formulated and implemented within a 10-year period.

<u>Grazing Guidelines</u>

The treatment of existing problems is presented in the section "Remedial Measures" in this chapter.

1. Stocking should be adjusted each year to a level that will maintain adequate vegetal cover for soil protection and improved grazing. Grazing season should be adjusted to avoid excessive damage to soils and vegetal cover that occurs when grazing takes place on soils that are saturated.

2. Severely eroded and unstable soil-slope areas should be closed to grazing because all the vegetation is needed for watershed protection.

3. Conversion of cutover timberland to grass should be limited to land with soils suitable for forage production on which sediment yield will not be increased. Such conversions require careful planning and sensible range management to prevent damage to the land. For economic reasons, good timber sites should not be converted to grass.

4. To avoid cover deterioration caused by concentrating grazing in small areas, livestock use should be distributed evenly over large areas.

5. On land in the slight erosion class, livestock numbers should be reduced slightly. Seed is plentiful and ground cover is generally adequate, but composition and vigor of stands should be improved through lighter use. In the long run, this will protect the soil and increase economic returns.

6. On land in the moderate erosion class, strong steps should be taken to bring livestock numbers into balance with the forage supply. These lands are frequently overstocked, and the reduction of livestock will increase forage and provide greater protection for the soil resource.

7. Grazing should be excluded entirely on land in the severe erosion class because all the vegetal cover is needed for protection of the soil.

8. In general, timberlands converted to grass should be replanted to trees. (See the section "Remedial Measures" in this chapter.)

<u>Deer Guidelines</u>

1. Deer populations should be reduced and held in proper relationship to available forage by harvesting a percentage of antlerless deer as well as bucks. This will maintain a healthy deer herd, protect the soil, and actually sustain a higher annual yield of harvestable animals and more hunting days per year. Continued educational efforts will be needed to counteract opposition to such hunting programs.

2. Deer hunting should be spread more evenly to better utilize and manage the resource. Much of the private land is closed to public hunting; however, most of it is hunted to some extent by private clubs or friends of the landowner. This tends to concentrate hunters on the national forest and other public lands. Game management programs should be adjusted and coordinated to encourage private landowners to harvest deer under realistic deer management plans.

3. On some cattle and sheep ranges, competition for feed between these domestic livestock and deer has a detrimental effect upon the land. In these cases, until a sound deer management program is adopted, numbers of domestic livestock must be reduced to achieve a balance between grazing use and available forage.

<u>Wildfire Guidelines</u>

The following guidelines are designed mainly to recognize and plan for the impacts that are anticipated as the basins become developed.

1. A fire protection program that will hold losses to approximately the present level should be maintained. As the watersheds are subjected to more intensive use, the value of land and developments will increase, more emphasis will be placed on landscape beauty, and fire risk will increase. Fire control planning by the California Division of Forestry

and the Forest Service is adequate to maintain the present level of protection, but additional manpower and equipment will be necessary.

2. Fire control and burned area rehabilitation practices that afford maximum protection to soil resources should be employed. Regardless of the level of fire protection, large fires may occasionally occur. To minimize soil damage and to rehabilitate these areas as quickly as possible the following should be considered.

   a. Although expediency often dictates fire fighting tactics that disturb large areas of soil, those in charge should understand the resource values involved and choose the alternatives that are least likely to cause soil erosion. The installation of erosion control measures on all areas disturbed by fire fighting activities, presently standard practice with the Forest Service and California Division of Forestry, should be continued and improved wherever possible.

   b. Salvage logging or any other activity within the burned area should be done under the guidance of the Erosion Hazard Rating System or similar systems. In many cases, the potential financial gain from these activities may not be worth the risk of increased erosion and of the loss of future productivity.

   c. The area should be seeded promptly to restore cover, and other emergency measures should be used to provide initial protection to the soil. Various specialists should be consulted to formulate the best total rehabilitation plan to eventually restore full productivity to all lands within the burned area.

Control Burning Guidelines

The guidelines listed below are keyed to the control burning done in connection with conversion. The effects of such conversion upon sediment yield are discussed in the chapter "Effects of the Recommended Program." Decisions about the feasibility and wisdom of conversions must be made with those considerations in mind. The guidelines presented here do not reflect a recommendation for or against conversions, but are designed only to make the use of fire and other conversion methods as safe and effective as possible.

1. Only sites with relatively stable soils that are capable of producing forage of a quality and quantity that will bring satisfactory economic returns and that will not readily revert to brush or other woody vegetation should be converted.

2. In general, conversions should be avoided on slopes over 30 percent.

3. A combination of herbicides, mechanical clearing, and control burning should be given preference over the use of fire alone for conversions. However, fire may be the only practical method for initial brush removal, especially in dense fields with heavy cover.

For maintenance of conversions, herbicides are generally more efficient, cheaper, and less detrimental to the site than repeated burning.

4. If it is necessary to seed and fertilize to obtain the optimum grass cover, a specific seeding prescription for each area should be obtained from a range management specialist.

5. Livestock grazing should be restricted and sometimes excluded until the grass cover is established and the seedlings have attained sufficient vigor to sustain themselves. Grass cover and plant vigor should be maintained at a satisfactory level through proper grazing management.

6. To help prevent escape of fire, control burns should be kept relatively small, probably 200 acres or less, depending upon terrain and vegetal conditions. Burns should be well planned to take advantage of weather conditions that will allow a successful conversion while minimizing the chance that the fire will escape, to assure full control at all times, and to provide for adequate post-fire treatment.

Recreation Guidelines

1. Since roads serving recreation areas will probably be located along important drainages and around reservoirs, they should be constructed and maintained in such a manner that erosion and soil loss are kept to a minimum. Specific guidelines are discussed in the section "Roads" in this chapter. Construction of scenic vista areas may require large road fills that will need special planning to guard against soil erosion.

2. Sites for concentrated recreation use along streambanks and lakeshores--such as public beaches, campgrounds, picnic areas, and boat launch facilities--should be carefully selected and developed so that trampling, wading, and removal of vegetation will not cause streambank erosion. Areas of unstable soils and other sites that are particularly susceptible to damage, such as outside curves of streams, should be avoided for development. Recreation development should be done under the guidance of professional recreation planners.

3. Foot and horse trails should be located, constructed, and maintained so as to keep soil loss to a minimum; adequate drainage is the most important consideration. Barriers should be placed to restrict vehicles to established roadway or parking surfaces, and foot travel should be confined to desired routes to reduce destruction of vegetal cover by trampling and to minimize soil compaction and erosion. To avoid permanent site damage, trails and unsurfaced roads should be closed during wet seasons. Camp and picnic sites and other areas where people congregate should be closed when use exceeds that which the soil can withstand.

Cropland Guidelines

To assure continued low sediment rates from present cropland and future cultivated land that may be developed on steeper slopes, the following management guidelines are recommended:

1. On-site investigations and detailed soil surveys should be used to determine management practices and remedial measures that are compatible with the great variety of soils and climates in the areas where these croplands are found.

2. The various educational, financial, and technical assistance programs of Federal, State, and county Agencies should be used to increase productivity and protect the soil resource.

3. Farm management practices that retard runoff and reduce sediment yield should be used; a suggested list is presented in the table "Guidelines for Land Use and Minimum Conservation Treatment of Land Suited for Cultivation" on the following pages.

STREAMBANKS

Remedial measures for control of streambank erosion are considered impractical, but the application of certain management guidelines will help to reduce the sediment yield from this source, especially in 2nd and 3rd Order channels. Since the guidelines are not practical in all areas or under all conditions, they should be applied with good judgment.

1. Clearing and snagging: Snags, drifts, sand bars, or other obstructions to channel flow should be removed to increase the channel capacity, to prevent bank erosion by eddies, to prevent the formation of sand bars, to minimize the occurrence of debris jams, and to eliminate the diversion of flows directly into erodible streambanks.

   (a) All trees, stumps, and brush within the perimeter of the channel, when cut, should be cut as close to ground level as the cutting tools will permit.

   (b) Large, bulky, and top-heavy trees that are undercut by streamflows and might topple over should be removed to avoid causing debris jams and deflection of streams.

   (c) Trees should be felled so as to avoid damage to other trees and the channel.

   (d) Trees, logs, and all combustible material resulting from clearing and snagging operations should be piled and burned above the high water mark.

   (e) Care should be taken not to destroy vegetation and ground cover on streambanks.

Guidelines for Land Use and Minimum Conservation Treatment of Land Suited for Cultivation

(By Land Capability Class and Subclass - L.C.S.)

L.C.S.	Area (Sq.Miles)	Land Management Problems	Suitable Alternate Agricultural Land Uses[1]	Minimum Conservation Treatment[2] - [3]
IIe	30	Erosion hazard due to sloping land. Some soils are gravelly and have lower available water capacity.	Irrigated Cropland Row Crops Field Crops	Conservation Cropping System Irrigation Water Management
			Orchard Vineyard Small Fruits	Cover and Green Manure Crop, or Minimum Tillage Irrigation Water Management
			Pastureland (and Hayland)	Pasture Proper Use Irrigation Water Management
			Non-irrigated Cropland Row Crops Field Crops	Conservation Cropping System Minimum Tillage
			Orchard Vineyard Small Fruits	Cover and Green Manure Crop, or Minimum Tillage
IIw	125	Overflow	Irrigated Cropland Row Crops Field Crops	Conservation Cropping System Irrigation Water Management
			Orchard Vineyard Small Fruits	Cover and Green Manure Crop, or Minimum Tillage Irrigation Water Management
			Pastureland (and Hayland)	Irrigation Water Management Pasture Proper Use
			Non-irrigated Cropland Row Crops Field Crops	Conservation Cropping System Minimum Tillage
			Orchard Vineyard Small Fruits	Cover and Green Manure Crop, or Minimum Tillage
		Somewhat poor drainage; maintenance of drainage system.	Irrigated Cropland Row Crops Field Crops	Conservation Cropping System Irrigation Water Management (drainage)
			Orchard (pears) Vineyard Small Fruits	Cover and Green Manure Crop, or Minimum Tillage Irrigation Water Management (drainage)
			Pastureland (and Hayland)	Irrigation Water Management Pasture Proper Use
			Non-irrigated Cropland Row Crops Field Crops	Conservation Cropping System Minimum Tillage (drainage)
			Orchard (pears) Vineyard Small Fruits	Cover and Green Manure Crop, or Minimum Tillage (drainage)

Guidelines for Land Use and Minimum Conservation Treatment of Land Suited for Cultivation

(By Land Capability Class and Subclass - L.C.S.)

L.C.S.	Area (Sq.Miles)	Land Management Problems	Suitable Alternate Agricultural Land Uses[1]	Minimum Conservation Treatment[2] - [3]
IIIe	20	Very gravelly soils that have low available water capacity. Erosion hazard due to sloping land.	<u>Irrigated</u> Cropland Row Crops Field Crops	Conservation Cropping System Crop Residue Use Irrigation Water Management Minimum Tillage
			Orchard Vineyard Small Fruits	Cover and Green Manure Crop, or Mulching Crop Residue Use Minimum Tillage Irrigation Water Management
			Pastureland (and Hayland)	Pasture Proper Use Irrigation Water Management
			<u>Non-irrigated</u> Cropland Field Crops	Conservation Cropping System Crop Residue Use Minimum Tillage
			Orchard Vineyard Small Fruits	Cover and Green Manure Crop, or Crop Residue Use Minimum Tillage Mulching
		Erosion hazard due to sloping land. Restricted rooting. Slow subsoil permeability	<u>Irrigated</u> Cropland Field Crops	Conservation Cropping System Irrigation Water Management Crop Residue Use Minimum tillage
			Orchard (marginal) Vineyard Small Fruits	Cover and Green Manure Crop, or Mulching Irrigation Water Management Minimum Tillage Sprinkler Irrigation System
			Pastureland (and Hayland)	Irrigation Water Management Pasture Proper Use
			<u>Non-irrigated</u> Cropland Field Crops	Conservation Cropping System Crop Residue Use Minimum Tillage
			Vineyard	Cover and Green Manure Crop, or Minimum Tillage. Mulching
IIIw	25	Somewhat poor drainage. Slow permeability. May have some salts.	<u>Irrigated</u> Cropland Row Crops Field Crops	Conservation Cropping System, Crop Residue Use Irrigation Water Management Minimum Tillage (Drainage)
			Pastureland (and Hayland)	Irrigation Water Management Pasture Proper Use (drainage)
			<u>Non-irrigated</u> Cropland Field Crops	Conservation Cropping System Crop Residue Use Minimum Tillage (drainage)

Guidelines for Land Use and Minimum Conservation Treatment of Land Suited for Cultivation

(By Land Capability Class and Subclass - L.C.S.)

L.C.S.	Area (Sq.Miles)	Land Management Problems	Suitable Alternate Agricultural Land Uses 1/	Minimum Conservation Treatment 2/ - 3/
IVe	570	Erosion hazard due to sloping land. Soil depth. Acidity for some crops.	Irrigated Cropland Field Crops (Hay)	Conservation Cropping System Crop Residue Use Irrigation Water Management Minimum Tillage Sprinkler Irrigation System
			Orchard (marginal in some areas) Vineyard	Cover and Green Manure Crop, or Mulching Crop Residue Use Sprinkler Irrigation System Irrigation Water Management Minimum Tillage
			Pastureland (and Hayland)	Irrigation Water Management Sprinkler Irrigation System Pasture Proper Use
			Non-irrigated Cropland Field Crops (not well adapted in some areas)	Conservation Cropping System Crop Residue Use Minimum Tillage
			Orchard (marginal in some areas) Vineyard (marginal in some areas)	Cover and Green Manure Crop, or Mulching Crop Residue Use Minimum Tillage
		Erosion hazard due to sloping land. Soil depth. Slow subsoil permeability. Acidity for some crops.	Irrigated Pastureland (and Hayland)	Sprinkler Irrigation System Irrigation Water Management Pasture Proper Use.
			Non-irrigated Cropland Field Crops (not well adapted)	Conservation Cropping System Crop Residue Use Minimum Tillage
			Orchard (existing) Vineyard(existing)	Cover and Green Manure Crop, or Mulching Crop Residue Use Minimum Tillage

1/ Other suitable alternate agricultural land uses for each of the Land Capability Classes and Subclasses are:
Non-irrigated Pastureland
Recreation Land and/or Wildlife Land
Some soils in Classes IIe, IIw, IIIe, and IVe are suited to Woodland.
Land uses not shown indicate their general unsuitability.

2/ Pasture Proper Use and Woodland Proper Use are the minimum conservation treatments for Non-irrigated Pastureland and Woodland, respectively.
No specific practices are indicated as minimum conservation treatment for Recreation Land and/or Wildlife Land because of the wide variety of activities that might occur under these land uses. Applicable conservation treatment should assure maintenance of land and water resources.

There are many structural and other conservation practices that are supplemental to the minimum conservation treatment practices.

3/ Definitions of minimum conservation treatment practices:

Conservation Cropping System - Growing crops in combination with needed cultural and management measures. Cropping systems include the use of rotations that contain grasses and legumes, as well as sequences in which the desired benefits are achieved without the use of such crops.

Cover and Green Manure Crop - A crop of close-growing grasses, legumes, or small grain used primarily for seasonal protection and for soil improvement. It usually occupies the land for a period of one year or less, except where there is permanent cover as in orchards.

Crop Residue Use - Utilizing plant residues left in cultivated fields to prevent erosion and improve the soil.

Irrigation Water Management - The use and management of irrigation water such that the quantity of water used for each irrigation is determined by the moisture-holding capacity of the soil and the need of the crop, where the water is applied at a rate and in such a manner that the crops can use it efficiently and significant erosion does not occur. (Includes the timing of irrigations to meet crop needs, the control and adjustment of stream sizes to prevent erosion, and the control of lengths of "set" to reduce water losses.)

Minimum Tillage - Limiting the number of cultural operations to those that are properly timed and essential to produce a crop and prevent soil damage.

Mulching - Applying plant residues or other suitable materials not produced on the site to the surface of the soil.

Pasture Proper Use - Grazing at an intensity that will maintain adequate cover for soil protection and maintain or improve the quantity and the quality of desirable vegetation.

Woodland Proper Use - Treating woodlands in a manner that will maintain adequate cover for soil and water conservation and maintain or improve the quantity and quality of desirable woods crops by the application of one or more woodland protection and/or woodland conservation practices.

(f) Where sand bars have built up, especially after heavy flooding, and have caused the channel to meander and cause raw banks to appear, removal of material to redirect flows away from the raw banks is sometimes necessary. The raw banks should then be shaped to a stable slope and planted with suitable vegetation to help reduce further bank erosion. Ideally, vegetal plantings, such as willow cuttings, should be protected against damage until they are established and become self-protecting. These willow plantings should not be allowed to constrict the channel.

(g) Where removal will result in channel erosion, either the clearing and snagging should not be done or other practices for the prevention of such erosion should be installed concurrently.

(h) Removal of vegetation toes of landslides should be done selectively and with good judgment.

2. Trash, debris, slash, or other materials should not be dumped into stream channels or left where it could reach channel flows.

3. Surface waters should not be discharged directly over the edges of the streambanks. Diverted flows from farm drainage ditches and road gutters should be provided with an adequate outlet.

4. Vegetal cover along streambanks should be encouraged as long as it does not become uncontrolled and restrict channel capacities.

5. Temporary earth fills that may be removed by flows each winter should not be constructed or should be removed each fall.

6. Strong action should be taken to control activities in and adjacent to stream channels and unstable areas. Regulations such as the Forest Practices Act, building codes, and regulations of planning commissions, fish and game commissions, road commissions, and other responsible bodies should be enforced to reduce sediment and alleviate debris problems. The general public should be informed of the problems and the consequences associated with streambank erosion.

7. The management guidelines for logging and road building activities (discussed elsewhere in this section) should be applied where appropriate since they are interrelated with those for streambanks.

LANDSLIDES

The following are land management guidelines for prevention and reduction of sediment yield from landslides influenced by man's activities:

1. Potential problem areas should be mapped and the maps made available to interested parties, such as loggers and roadbuilders, so they can plan their operations accordingly.

2. Logging operations should be planned well in advance so that erosion and geologic hazards can be evaluated and activities can be adjusted to avoid problem areas.

3. Landslides should be logged only by skyline or similar systems that minimize soil disturbance.

4. Logging roads, skid trails, and landings should not be built on landslides or in geologically unstable areas.

5. Grazing should be eliminated in areas experiencing rapid soil creep (areas of rumpled topography and minor sliding).

6. Conversion of timberland to grassland should not be made on landslides or in geologically unstable areas.

7. The management guidelines for logging, grazing, roads, and streambanks (discussed elsewhere in this section) should be applied where appropriate since they are interrelated with those for landslides.

ROADS

1. Soil and geologic conditions should be investigated so that road locations can be planned to avoid steep slopes and areas of unstable soil and rock. In potential problem areas, excavation and soil disturbance should be reduced even though the best alignment may sometimes be sacrificed.

2. Roads should be constructed during the dry season.

3. Large fills and waste accumulations should not be allowed near channels. Where possible, cut slopes should be no steeper than $1\frac{1}{2}$ to 1, and fill slopes no steeper than 2 to 1. All cut and fill slopes that will support vegetation should be protected from erosion by seeding grasses, planting shrubs or trees, and applying mulch and fertilizer.

4. Excess material should be end-hauled to selected disposal sites away from streams, where it can be protected against erosion.

5. All fills should be compacted during construction.

6. When it is absolutely necessary to construct roads in unstable soil and landslide areas, special surface and subsurface drainage should be provided.

7. Roads should be located so that fills will not encroach upon streams during peak flows. Riprap and retaining walls should be provided to protect fills when it is necessary to locate them within high-water elevations at culvert or bridge crossings.

8. Fording of live streams with construction equipment should be avoided.

9. The location of stream crossing points should be selected to minimize the disturbance to streambanks and streamflow. Bridges or culverts should be provided at all watercourses for both temporary and permanent roads. Bridge piers and abutments should be aligned to minimize deflection of current. Culverts should be designed to permit the free movement of fish.

10. Adequate surface drainage facilities should be installed. Down-drains and energy dissipators should be installed at outlets of drainage ditches and culverts to prevent outflow water from being discharged directly onto unprotected slopes. Whenever possible, culvert outlets should be located in existing waterways or in rocky areas. In erodible channels, energy dissipators should be provided at culvert outlets. Surfaced dips or outsloping should be considered for lower-standard roads to prevent accumulation of drainage flows.

11. All roads that will be used during the wet months should be surfaced.

12. All drainage ditches, dips, and culverts should be inspected each year and repaired or cleaned out prior to the rainy season. Maintenance operations should not remove the toe of cutbanks, and the excess material should not be deposited on streambanks.

13. Cut and fill areas should be inspected periodically for possible maintenance needs.

RECOMMENDED PROGRAM

This chapter presents the recommended portions of the potential land treatment program presented in the previous chapter. Recommendations are based on feasibility for a basinwide installation and include all of the management guidelines and a few remedial measures.

REMEDIAL MEASURES

Recommended remedial measures include only those for private grassland, as described in the chapter "Potential Land Treatment Program." The high cost of maintaining an acre-foot of soil in place made it apparent that the other proposed remedial measures would not be feasible for a basinwide installation. A detailed study would probably show that these other remedial measures are feasible to solve localized problems.

NATURAL GRASSLAND

Proper grazing management is the most important measure that can be applied to these lands and should be employed on all grassland whether or not the rest of the program has been installed.

Land in the slight erosion class (267 square miles) should be seeded and fertilized, and an additional 104 square miles should be fertilized only. To maintain good grass production, all 371 square miles should be fertilized every third year.

Four square miles of land in the moderate erosion class should be seeded and fertilized, with followup fertilization every third year.

Land in the severe erosion class (44 square miles) should be fertilized, and 100 miles of permanent fence should be built to exclude livestock.

Technical assistance should be provided to help ranch owners select the areas to be treated, to determine the best method of treatment for each soil and cover condition, and to bring livestock numbers into balance with the grass forage supply.

CONVERTED TIMBERLAND

Proper grazing management is the most important measure that can be applied to these lands and should be used on all grassland that is intended to be converted to timberland as well as those areas that will remain in grassland.

About 120 square miles of land in the slight erosion class should be reforested, and 45 miles of temporary fence should be built to exclude livestock while the trees are small. Land in the moderate and severe erosion classes should remain in grass cover and should not be treated. The seven square miles of land in the severe erosion class is included in the severe erosion class for natural grassland.

Technical assistance should be increased to help landowners select the land to be reforested and apply proper grazing management to the remaining grassland.

COST

Costs of the remedial measures for private grassland were estimated for the 20-year installation period. Many choices of seed and fertilizer combinations could be used to bring about the desired improvement in vegetal cover; however, to simplify cost estimates, only a basic few were selected for the costs shown in the table "Estimated Costs of Remedial Program for Private Grassland" on the next page. Prices were determined from local suppliers, and the quantities were estimated by the USDA River Basin Staff.

The total cost of installing the remedial measures is $15,659,000, an average annual cost of $783,000 for the 20-year period. After the 20-year installation period, an annual cost of $442,000 would be required for followup fertilization. Since there will be no maintenance cost the first year and the cost will not reach a maximum until after the 20th year, it will average about 50 percent of the regular amount, or $221,000 per year. The total annual cost will be about $1 million for the first 20 years and about $442,000 thereafter.

MANAGEMENT GUIDELINES

All of the management guidelines presented in the chapter "Potential Land Treatment Program" are recommended for basinwide use to protect against future sediment yield problems. These guidelines are general and may not be practical in every case or condition. Technical guidance should be obtained in planning a program of appropriate guidelines to use for each piece of land.

IMPLEMENTATION

A large land treatment program has certain implementation problems and needs that must be overcome before a basinwide installation can be successful. This section presents major problems and needs that may be encountered in installing the program.

PROBLEMS

The success of the program depends entirely on the voluntary participation of the private landowners and operators. Many of the agricultural enterprises in the basins are marginal operations, and landowners show little apparent interest in spending money for improvements. The entire North Coastal Area is considered an economically depressed area by the Economic Development Administration. Under its authority, Humboldt, Mendocino, Trinity, and Lake Counties are qualified for full financial assistance, and Glenn County is eligible for grants.

Although the proposed remedial measures are economically sound, the returns are sometimes not realized for long periods. In the case of reforestation measures, it will be about 10 to 15 years before any income will be received

Estimated Costs of Remedial Program
for Private Grassland

Item	Area (Square Miles)	Total Cost[1] ($)	Annual Maintenance Cost[2] ($)
Natural Grassland			
Slight Erosion Class (371 square miles)			
Seeding	267	2,905,000	
Fertilization	371	6,107,000	415,000
Subtotal		9,012,000	415,000
Moderate Erosion Class (4 square miles)			
Seeding	4	51,000	
Fertilization	4	66,000	4,000
Subtotal		117,000	4,000
Severe Erosion Class[3] (44 square miles)			
Fertilization	44	295,000	
Permanent Fencing	44	200,000	8,000
Subtotal		495,000	8,000
Converted Timberland			
Slight Erosion Class (120 square miles)			
Tree Planting	120	5,376,000	
Temporary Fencing	120	59,000	
Subtotal		5,435,000	
All Lands			
Technical Services[4]	762	600,000	15,000
Total		15,659,000	442,000

1/ Costs are based on a 20-year installation period.

2/ Annual maintenance cost after the 20-year installation period. During the 20-year installation period, annual maintenance costs will be one-half this amount.

3/ Includes 7 square miles of severely eroded converted timberland that should not be grazed or used as timberland.

4/ 74 percent ($444,000) should be prorated to grassland, based on the area.

from the sale of Christmas trees and at least another 60 years before the major income will be made from timber harvests. Even grazing benefits may not be realized for the first year or two until the grassland is rehabilitated.

Land in the severe erosion class would be excluded from livestock grazing, and therefore, would yield little or no income. Landowners would probably still have to pay property taxes based on grazing use, which could discourage landowners from participating in the program.

Many landowners do not live on their property and are often not aware of the erosion problems that can be created by unconcerned operators or leasees. Some people buy land mainly for speculation of future sale profits, and these owners are seldom interested in spending money for improvements, especially when the benefits are long term.

Under the Agricultural Conservation Program, administered by the USDA Agricultural Stabilization and Conservation Service, Federal funds are available on a cost-sharing basis to install remedial practices for soil and water conservation problems. For many of these practices, the Federal cost share is too small to encourage landowners to make the large investments necessary to install the recommended program.

NEEDS

Before the remedial measures on private grassland can be installed, detailed surveys of soils, grass cover conditions, and needs must be made. A conservation plan listing specific treatments for each problem area should be developed with each landowner. Detailed economic studies are needed to evaluate all on-site and downstream benefits that will accrue from installing both the remedial measures and the management guidelines. There are unevaluated downstream benefits and some long term on-site benefits that will accrue to the general public as a result of the installed program. These include improved water quality, reduced sediment yield, improved fish and wildlife habitat, increased recreational value, increased land value, reduced road maintenance, increased scenic beauty, and protection of the grassland resource for future use.

A special study should be made on cost sharing to arrive at an equitable distribution of program installation costs between public and private interests.

An effective educational and informational program is essential to the success of the program. Landowners, local officials, and the general public should be made aware of the need for a land treatment program and the benefits that can be derived from its installation. Local officials and landowners should be aware of the possible erosion problems that may result from construction projects that lack proper planning and careful installation, and they should be informed of the technical consulting services and financial assistance programs available to them through Federal and State agencies.

Property tax assessments on land to be excluded from livestock grazing should be studied in detail to determine an equitable method of compensating

the landowner for this financial loss. Tax relief could be accomplished through local public funds by removing these lands from the tax rolls or reducing the taxes to a minimum, or compensation could be made by State or Federal funds that would spread the costs over a larger tax base. It would be desirable to make studies regarding the capability of specific areas to provide light recreation use, such as hunting. The income from such enterprises may be sufficient to pay the property taxes and relieve the public of this burden. The initial installation of such a program may require cost-sharing from public funds.

This chapter presents the physical, biological, and social effects of the recommended land treatment program.

SEDIMENT YIELD REDUCTION

Estimates of reduction in sediment yield from installation of the recommended program are presented for each sediment source and cause and reflect reductions expected by the year 2020.

The following tabulation presents the estimated future annual sediment yields in the Eel and Mad River Basins by principal sources and subbasins with the recommended program installed:

	Future Sediment Yield with Program (Acre-feet/year)				
Subbasin	Streambanks	Landslides	Sheet & Gully	Roads	Total
Outlet Creek-Pillsbury	371	188	312	26	897
Middle Fork	821	366	167	21	1,375
South Fork	572	621	109	20	1,322
Van Duzen	602	474	70	8	1,154
Main Eel	3,997	1,517	226	15	5,755
Eel Basin Subtotal	6,363	3,166	884	90	10,503
Mad Basin Subtotal	1,043	449	105	7	1,604
Basins Total	7,406	3,615	989	97	12,107

This tabulation reflects the reduction of sediment yield that could be achieved by installing the remedial measures proposed for privately owned grassland and by following the management guidelines.

The influence that the major reservoirs proposed under the State Water Project will have upon sediment yield has not been included in the foregoing tabulation. This development program is now under study, and plans will not be firm for several years.

The proposed reservoirs will probably influence sediment problems downstream. Controlled releases from the reservoirs should reduce the sediment yield from streambanks and from those landslides adjacent to streams. These controlled releases could also have a detrimental effect in that sediment deposited in the mainstream from tributaries below the dams may not be flushed out as it is now. Within the reservoir area, streambank erosion and possibly landslides would be essentially eliminated.

SHEET AND GULLY EROSION

The table on the following page presents the estimated future annual sediment yields by causes for sheet and gully erosion in the basins with the land treatment program installed.

If the land treatment program is installed, the sediment yield from sheet and gully erosion will be reduced about 332 acre-feet, or 25 percent below that expected under the assumed future management. No attempt was made to estimate the effects of partially following the guidelines or installing only parts of the remedial program. It can be reasoned that any improvement in management or the installation of any part of the remedial measures will affect sediment yield to some degree.

Over 41 percent of the expected future sediment yield from sheet and gully erosion is attributed to natural causes, and this proportion is expected to remain substantially the same, with annual variations dependent upon rainfall, particularly on the occurrence of floods. If the 546 acre-feet attributed to natural causes is deducted from the estimated 1,321 acre-foot total annual sediment yield, the remaining 775 acre-feet represents the portion of the sediment yield that is affected by man's activities. Therefore, the predicted reduction of 332 acre-feet from the installation of the land treatment program represents about 43 percent of that portion of sediment yield influenced by man.

Privately Owned Grassland

Remedial measures on privately owned grassland would reduce sediment yield by varying amounts throughout the basins. The following tabulation presents the predicted area of each erosion class by the year 2020 and the estimated corresponding sediment yield, with and without installation of the remedial measures:

Erosion Class	With Remedial Measures: Area (Sq.Miles)	With Remedial Measures: Annual Sediment Yield (Acre-Feet/Year)	Without Remedial Measures: Area (Sq.Miles)	Without Remedial Measures: Annual Sediment Yield (Acre-Feet/Year)
Natural Grassland				
Slight	376	56	362	56
Moderate	149	60	160	101
Severe	37	33	40	87
Subtotal	562	149	562	244
Converted Timberland				
Slight	158	24	135	32
Moderate	35	14	55	53
Severe	7	6	10	33
Subtotal	200	44	200	118
Total	762	193	762	362

Average Annual Sediment Yields from Sheet and Gully Erosion by Causes for the Eel and Mad River Basins (Future with the Land Treatment Program)

Basins, Subbasins, and Watershed Units	Area (Square Miles)	Total (Acre-Feet/ Year)	Directly Influenced by Man: Logging	Burning	Grazing	Temporary Roads	Other: Deer	Natural
			(Acre-Feet Per Year)					
EEL RIVER BASIN								
Outlet Creek-Pillsbury Subbasin								
Lake Pillsbury	347	203	1	3	6	2	53	138
Scott Dam Subunit	(287)	(183)	(1)	(3)	(5)	(2)	(48)	(124)
Pressley Subunit	(60)	(20)	(T)	(0)	(1)	(T)	(5)	(14)
Outlet Creek	163	33	T	T	6	0	7	20
Willis Ridge	199	76	T	4	10	0	6	56
English Ridge Subunit	(142)	(56)	(T)	(4)	(6)	(T)	(4)	(42)
Rodeo Valley Subunit	(57)	(20)	(T)	(T)	(4)	(0)	(2)	(14)
Subtotals	709	312	1	7	22	2	66	214
Middle Fork Subbasin								
Wilderness	205	56	1	6	T	3	12	27
Black Butte	162	45	2	2	6	1	9	25
Williams - Thatcher	116	24	T	T	4	T	5	15
Covelo	99	9	T	0	3	0	T	6
Elk Creek	115	21	1	T	4	T	4	12
Dos Rios	56	12	T	T	5	0	2	5
Subtotals	753	167	4	8	29	4	32	90
South Fork Subbasin								
Laytonville	125	26	1	1	4	T	6	14
Lake Benbow	413	67	7	2	11	0	17	30
Humboldt-Redwoods	152	16	1	T	4	0	3	8
Subtotals	690	109	9	3	19	T	26	52
Van Duzen Subbasin								
Yager Creek	132	22	1	T	8	0	2	11
Van Duzen River	297	48	4	1	16	1	4	22
Subtotals	429	70	5	1	24	1	6	33
Main Eel Subbasin								
North Fork	283	94	T	T	11	1	18	64
Bell Springs	335	70	1	1	26	0	2	40
Sequoia	187	21	1	T	8	T	2	10
Larabee Creek	84	13	1	T	5	T	1	6
Lower Eel	214	17	1	T	7	0	1	8
Eureka Plain	221	11	1	T	3	0	1	6
Subtotals	1,324	226	5	1	60	1	25	134
EEL RIVER BASIN TOTALS	3,905	884	24	20	154	8	155	523
MAD RIVER BASIN								
Ruth	143	26	T	0	1	0	18	7
Butler Valley	250	35	7	1	6	T	13	8
North Fork	47	5	1	T	1	0	2	1
Blue Lake	65	4	T	T	2	0	T	2
Subtotals	505	70	8	1	10	T	33	18
Little River	46	1	T	T	T	0	1	0
Big Lagoon	84	2	1	0	T	T	1	0
Subtotals	130	3	1	T	T	T	2	0
Snow Camp	68	8	2	T	2	0	2	2
Beaver	107	11	3	T	2	0	4	2
Orick	119	13	7	T	1	0	3	1
Subtotals	294	32	12	T	5	0	9	5
MAD RIVER BASIN TOTALS	929	105	21	1	15	T	44	23
EEL AND MAD RIVER BASIN TOTALS	4,834	989	45	21	169	8	199	546

STREAMBANKS

It is estimated that implementing all management guidelines would reduce the future sediment yield of 9,258 acre-feet per year for streambanks without the program to 7,406 acre-feet per year. This prediction is based on the assumption that the guidelines would be about 75 percent effective in reducing the sediment yield influenced by man.

LANDSLIDES

If the management guidelines are adopted, the estimated future sediment yield from landslides of 4,500 acre-feet per year will be reduced to 3,615 acre-feet per year, which is the present sediment rate. This reduction is based on the assumption that the guidelines would be 60 percent effective in controlling the sediment yield influenced by man.

ROADS

The adoption of management guidelines for future road construction would reduce the predicted future sediment yield from roads of 144 acre-feet per year to 97 acre-feet per year. The effectiveness of guidelines in reducing sediment yield is assumed to be 65 percent.

INCREASED LAND PRODUCTIVITY AND VEGETAL COVER

Increased land productivity is the most important effect of the reduction in land loss that is possible through installation of the recommended program. Once land is severely eroded, the chances for regaining maximum potential productivity are negligible. If the program accomplishes nothing more than reducing the severe erosion of our irreplacable soil resource, it is well worth the effort and expense. In general, the quality and vigor of the vegetation will be increased.

TIMBERLAND

The proposed management guidelines will leave the present vegetal cover types essentially unchanged, but the amount of bare ground left after timber harvest will be reduced. Vegetal protection for the land will be regained faster, and the fertility of the soil will be better protected. Timber production will increase, and this important resource will be conserved for future use.

NATURAL GRASSLAND

The following table presents the estimated annual number of animal-unit-months of grazing on the 562 square miles of natural grassland available under present conditions and under future conditions by the year 2020 with and without recommended remedial measures:

Erosion Class	Annual Animal-Unit-Month Production: Present Condition	With Remedial Program	Without Remedial Program
Slight	135,000	398,300	129,700
Moderate	76,000	77,700	80,900
Severe1/	0	0	0
Total	211,000	476,000	210,600

1/ Current animal-unit-month production from these areas is so low that it is considered to be zero, and the recommended remedial measures exclude livestock for future use.

Without installation of the remedial measures, there would be some shifting of areas from one erosion class to another, as shown by the tabulation under the private grassland portion of the sediment yield reduction section in this chapter. Some land in the slight erosion class will deteriorate and be classified as moderate erosion class land. Therefore, the forage production for the moderate erosion class, as shown in the table, will increase because of the increase in area. With the remedial measures, the forage production increases only slightly on lands in the moderate erosion class because only a small area will be fertilized.

The forage production from natural grassland for the year 2020 with the remedial program is estimated to be 265,400 AUM's more than that without the program; this net difference is a measure of on-site benefits. An additional benefit would be realized by keeping livestock numbers in balance with forage production, which will tend to increase the percentage of surviving lambs and calves.

CONVERTED TIMBERLAND

Substantial benefits in the form of reduced soil erosion and sediment yield and increased financial returns will eventually result from the re-establishment of forest vegetation, which is recommended for 120 of the 200 square miles of converted timberland. The reconversion of these lands is a slow process, and for several years both sediment reduction and financial benefits will be small. If the forest is properly managed, then new plantation will become established in about 10 years and sediment yield will drop significantly. The land will begin producing Christmas trees, poles, and other intermediate forest products in about 15 years and, in 60 to 80 years, sawlogs on a sustained yield basis.

HYDROLOGY

SHORT DURATION RUNOFF

Utilizing stream flow records available for the basins, a number of hydrologic studies were made in an attempt to determine effects of historical changes in land use upon runoff from short duration storms (up to 10 days). Results of these analyses were inconclusive because the effects were less

than the inherent errors associated with measuring precipitation and runoff quantities.

The USDA has, over a period of many years, conducted studies of effects of changes in hydrologic condition and land use upon peak rates and short duration runoff for comparatively small agricultural and range-type watersheds. From these studies certain general relationships have consistently shown up and have been incorporated into empirical procedures that are currently used to evaluate the impact of land use changes upon runoff.

Runoff characteristics were compared for three types of vegetal cover -- grassland, logged land, and converted timberland. Present cover conditions and those that might be expected with the installation of the land treatment program were estimated. For comparison of the more frequent, smaller storms, the 2-year frequency precipitation for short durations (up to 10 days) was used. Empirical methods developed by the Soil Conservation Service[1/] were used to determine the direct runoff volumes.

Under the proposed land treatment program, vegetal cover conditions on grassland in the moderate and severe erosion classes would be improved to that of the slight erosion class, and the short duration runoff would be reduced by an estimated 8 percent. If those lands suitable for forests that were previously converted from timber to grass are reconverted to timber and the rest of the converted timberland is improved as grassland, the short duration runoff would be reduced by about 27 percent after a recovery period of 18 years. The short duration runoff from logged areas would be reduced by an estimated 7 percent if the recommended management guidelines were used.

Since the lands that would be improved are only a small part of the basins, the short duration runoff for the entire basins would be reduced by only an estimated 3 percent. The effects of the reduced runoff would be more significant in streams adjacent to the improved areas than they would be in the downstream areas. The percent reduction in runoff will be less during the larger storms than it will be for the smaller ones.

FLOOD CONTROL

Since the study of U. S. Geological Survey gage data to show man's effects on runoff was inconclusive, a similar study on peak flows was abandoned. If the recommended program is installed, the peak flows would be reduced by a greater amount than that for the short-duration runoff. This reduction would still be small and would provide only minor flood control, especially in the lower reaches of the main rivers and in the plains area, where the major flooding takes place.

1/ U. S. Department of Agriculture, Soil Conservation Service, Hydrology Part I - Watershed Planning, National Engineering Handbook, Section 4, chs. 7-10. (Washington, D. C., August 1964).

WATER QUALITY

The overall water quality is not expected to be materially affected by the recommended program, but the periodic sedimentation that occurs during the major runoff period would be reduced, especially in the smaller streams in the uplands. The chemical characteristics of the water should remain unchanged except for a possible minor increase in nitrogem caused by fertilization of private grassland. A preliminary study indicates that the increase in nitrogen content from the fertilizer would be negligible.

IMPROVED FISH AND WILDLIFE

If the recommended program is installed, the number of fish eggs lost through erosion and sediment deposition would be reduced, spawning beds would be improved, and the population of anadromous and other fish would be increased. As the vegetal cover is improved, wildlife habitat will be enhanced and game populations will increase.

INCREASED SCENIC BEAUTY, RECREATION, AND LAND VALUES

Installation of the recommended program will improve the natural beauty of the area. Some ugly scars created by erosion on the hillsides, especially those caused by man's activities, will be replaced with vegetation that will return the natural green and gold appearance.

With the improved effects of the program previously discussed, recreation opportunities will increase. Hunting and fishing will be better because of the increased number of fish and game. More people will engage in tourism, camping, and other forms of recreation.

Improvements in productivity, recreation, and scenic beauty will increase the value of the land.

ECONOMIC AND SOCIAL BENEFITS

Incomes from improved productivity on private grassland and timberland will be increased through installation of the recommended program, and enterprises will be placed on a sounder financial basis. The secondary effects from this increase in primary income are that increased profits will be realized by supporting industries and local business, and the existing underemployment will be reduced. In general, the overall living conditions in the basins will improve.

Management guidelines for future road construction will reduce operation and maintenance costs. These roads will be safer and more useful during and after intense storms. There will be less chance for travelers to be stranded and for communities to be isolated during major storms.

Recreation is the third largest land use in the basins and is an important source of local income. With the predicted increase in recreation from installation of the program, the income from this source will increase accordingly.

OPPORTUNITIES FOR DEVELOPMENT THROUGH USDA PROGRAMS

The United States Department of Agriculture has the authority and responsibility, under various laws, to promote wise use of land and water resources through land treatment and construction programs. The following is a summary of the development programs that are considered applicable to the Eel and Mad Basins and an assessment of their ability to accomplish the land treatment work.

DEVELOPMENT PROGRAMS

WATERSHED PROTECTION AND FLOOD PREVENTION PROJECTS (PUBLIC LAW 566)

The Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Congress, as amended) authorizes the expenditure of Federal funds through the U. S. Department of Agriculture to plan and carry out a program for the development, use, and conservation of the Nation's soil and water resources. The primary purpose of potential projects must be flood prevention, irrigation, or drainage; other purposes such as recreation, fishery enhancement, municipal and industrial water supply, and other water management measures may also be included. Except for rights-of-way and utility relocation, the program provides all installation costs for flood prevention projects and up to 50 percent of installation costs for all other purposes except municipal and industrial water supply.

SOIL CONSERVATION DISTRICT PROGRAMS

Soil conservation districts are legally constituted units of State government that administer soil and water conservation work within their boundaries. Each district is governed by an elected board of local people, usually resident landowners or operators, and has the authority to enter into working agreements with other government agencies, soil conservation districts, and with private interests.

The following conservation districts cover about 55 percent of the Eel and Mad River Basins:

Soil Conservation District	County	SCS Work Unit Office
Elk Creek SCD	Glenn	Willows, California
Mendocino Co. SCD	Mendocino	Ukiah, California
Trinity Co. S&WCD	Trinity	Redding, California
Westlake SCD	Lake	Lakeport, California

There are no soil conservation districts in Humboldt County, which comprises the remainder of the basins.

The Soil Conservation Service has working agreements to provide assistance to these districts. District programs, which are carried out through cooperative agreements with individuals or groups, include: (1) the treatment and use of cropland, rangeland, woodland, and forest, including the problems incident to their conversion to urban uses; (2) the improvement and protection of stream channels; and (3) the development of water for irrigation, livestock, and recreation. Increasing emphasis is being given to the management and protection of the steep and eroding mountain slopes.

About 75 percent of the privately owned grassland in the basins is within one of the four soil conservation districts. Each district is in a position to take leadership in implementing the land treatment program within its jurisdiction.

CONSERVATION OPERATIONS (PUBLIC LAW 46)

Public Law 46, enacted by the 74th Congress, established a national soil and water conservation policy and created the Soil Conservation Service (SCS). The law directed the SCS to develop a program to control and prevent soil and water losses and to reduce flooding and sediment hazards.

The SCS has no enforcement powers, but carries out its responsibilities through working agreements with organized soil and water conservation districts. Technical services are available to districts and their cooperators to assist in planning, designing, and applying conservation practices. These services include soil surveys to help determine the capability and best use of land; planning to help determine needed conservation measures and programs; and engineering and geologic services to investigate, design, and assist in the installation of structural measures. Technical services dealing with agronomy, biology, range management, and recreation are also available; however, according to the law, no funds are provided for installation of programs.

The technical services needed to install the recommended remedial measures, especially those in the grazing portion of the program, could be supplied by the SCS under its Conservation Operations Program. Technical services for the grazing program were estimated to be 74 percent of the total, or about $22,000 a year during the 20-year installation period and $11,000 a year thereafter.

AGRICULTURAL CONSERVATION PROGRAM

The Agricultural Stabilization and Conservation Service (ASCS) administers the Agricultural Conservation Program (ACP), through which they share with landowners and operators the cost of installing conservation measures. This allows the installation of measures that are too expensive for private landowners, but that have long term benefits.

The ASCS State Office determines the measures that are eligible for cost sharing in the State and sets the maximum allowable payment rate. A County Committee comprised of five farmers, is elected annually by the farmers in each county and is assisted by a local office manager and staff. After considering the most urgent conservation needs of the county, the Committee determines which of the eligible measures will be offered and establishes the local cost-sharing rates. Generally, the rates do not exceed 50 percent of the cost, but for erosion control practices the rate may be as high as 80 percent.

All of the recommended remedial measures are eligible for cost sharing under the ACP program. The 1969 Federal cost-share is about 50 percent for seeding, fertilizing, and fencing and is 80 percent for tree planting. Assuming that ACP funds for each county were spread uniformly over that county, the total amount available to the Eel and Mad River Basins in 1969 would have been $115,000 from the portions of the five counties involved.

There is a possibility of formulating a special ACP project within the basins that would set up a special allotment. The maximum amount that would probably be available to the basins under this type of project is about $200,000 a year.

FARM AND HOME ADMINISTRATION LOAN PROGRAMS

The Farmers Home Administration (FHA) provides loan programs and financial and advisory assistance for:

1. Farmers to purchase and improve real estate; to buy livestock, equipment, and other essentials; and to finance forestry and recreational enterprises.

2. Farmers and rural residents to construct, purchase, or improve homes, farm service buildings, housing for domestic labor, and rental housing.

3. Groups of farmers and rural residents to develop and improve rural water supply systems, waste disposal systems, rural outdoor recreational facilities, and livestock grazing land. In addition, loans can be made to organizations to finance the local share of the cost of installing Watershed Protection (Public Law 566) works of improvement.

4. Low-income rural families, on an individual family or cooperative group basis, to enable them to increase their incomes and make a modest improvement in their standards of living through loans for both agricultural and business enterprises.

In addition, FHA provides assistance to rural communities for planning, financing, and executing a complete program of economic development, including assistance in locating and using services of non-USDA programs to solve problems. The loan programs do not compete with those of other lenders, and financial management assistance accompanies each loan. Landowners who qualify for loans through private lending organizations are not

eligible for loans under the FHA programs. The maximum loan available under the Soil and Water Conservation Loan Program is $60,000.

FHA could loan money to qualified private landowners to pay their cost-share of installing the remedial measures. In 1969, FHA had about $1 million available for this type of loan for the entire State, but to date, there have been no loans made for grazing improvements in California.

AGRICULTURAL EXTENSION SERVICE

The Agricultural Extension Service (AES) provides educational and informational services to landowners and operators and maintains an office in each county in the Eel and Mad River Basins. University of California farm advisors help the agricultural interests to keep up-to-date on the latest agricultural advances and to improve farming operations. Livestock improvement and field trials on crops and fertilizers are part of AES activities. Financing is cooperative, with the University furnishing 60 percent, the County 20 percent, and the Federal government 20 percent of the funds for these services. Extension foresters based at Eureka and Ukiah provide research data and other educational material to timberland owners, conduct field research in forestry, and give advice and help timberland owners in managing their lands.

The farm advisors' offices and counties they serve are listed below:

Farm Advisor Location	County
Eureka	Humboldt
Ukiah	Mendocino
Weaverville	Trinity
Orland	Glenn
Kelseyville	Lake

AES could provide leadership in the educational and informational program to make landowners and the general public aware of the need for the land treatment program and the benefits that can be derived from its installation. Their technical advice on fertilization, seeding, livestock management, and forestry would be valuable assistance in applying the grazing portion of the land treatment program.

RESOURCE CONSERVATION AND DEVELOPMENT PROJECTS

The U. S. Department of Agriculture, by authority of Public Law 87-703, the Food and Agriculture Act of 1962, gives technical, direct financial, and loan assistance to local groups for conserving and developing local natural resources. Also, it helps project sponsors seek funds and services from other Federal agencies and from State and local sources. The Soil Conservation Service has leadership for the U. S. Department of Agriculture in this program.

Resource Conservation and Development (RC&D) projects usually include more than one county and are initiated and run by local people. Each area should be large enough to include the resource developments needed to meet project objectives but small enough for effective local leadership to prepare and carry out a project plan. Applications for a project are sent to the U. S. Department of Agriculture through one or more legal sponsors -- a qualified local group such as a conservation district, a county governing body, a town, a local or State agency, or a public development corporation.

Each Resource Conservation and Development project has its own unique goals, but typically they aim to:

1. Develop land and water resources for agricultural, municipal, or industrial use and for recreation and wildlife.

2. Provide soil and water resource information for a variety of land and water uses including farming, ranching, recreation, housing, industry, and transportation.

3. Provide conservation measures for watershed protection and flood prevention.

4. Accelerate the soil survey where it complements project measures.

5. Reduce pollution of air and water.

6. Speed up conservation work on individual farms, ranches, and other private holdings and on public land.

7. Improve and expand recreation facilities; promote historical and scenic attractions.

8. Encourage existing industries to expand and new ones to locate in the area and thus create jobs; encourage industries to process products of the area.

9. Improve markets for crop, livestock, and forest products.

Through a Resource Conservation and Development project in the Eel and Mad River Basins, technical and financial assistance could be made available to plan and install the remedial measures and to provide information services necessary for implementing the management guidelines.

Based on the average allotment of funds to RC&D projects in the Nation, the maximum amount available to install remedial measures would probably be about $110,000 a year. Additional funds would be available to cover the cost of technical services for the grazing measures.

COOPERATIVE STATE-FEDERAL FORESTRY PROGRAMS

Within the Eel and Mad River Basins, several cooperative State-Federal Forestry Programs are in progress, but only those that bear directly upon the sediment yield problem will be discussed. These programs are based upon

Federal laws designed to promote better forest management on non-national forest lands.

The Cooperative Fire Control Program, authorized by the Clarke-McNary Act of 1924, is administered by the State and allows the USDA Forest Service to assist the State in providing a satisfactory level of fire protection on non-federal forest and watershed land. This assistance is in the form of matching funds for fire protection and technical guidance where needed. Historically, California has furnished most of these funds. This program is helping to keep wildfire burn acreage and the resulting sediment at an acceptable level. It will become more important as fire hazard increases.

Under the Cooperative Forest Management Act, Service Foresters, employed by the California Division of Forestry and financed from Federal funds on a matching basis, are assigned to provide technical assistance to small private timberland owners. These Service Foresters advise the owners on methods of improving management to obtain optimum returns from timber resources and commercial recreation by applying multiple-use concepts. The headquarters of the Service Foresters and the counties served are located as follows:

Headquarters	County
Fortuna	Humboldt and Western Trinity
Willits	Mendocino

The portions of Lake and Glenn Counties that lie in the basins are in national forests, so no Service Foresters are needed. This program has been highly successful in the basins, and there is a need for more service than the two offices can provide.

For California in 1969, the Federal share for this program was \$53,000, and the State share was \$103,774. Assuming the same percentage of cost-sharing in the Eel and Mad Basins, the Federal share would be about \$3,000 and the State share about \$5,000 to provide the necessary technical services for the reforestation portion of the remedial measures. Although cost-sharing data is not available for the basins, it appears that adequate State and Federal funds could be furnished for technical services.

Under the General Forestry Assistance Program, the Forest Service provides technical assistance directly to industrial foresters, forestry consultants, large landowners (those owning over 5,000 acres of timber), other Federal agencies, and states. The technical assistance is directed toward developing, managing, and utilizing forest resources under the multiple-use concept so that they will contribute the maximum benefits to the economy, natural beauty, and resource wealth of the nation.

The Cooperative Tree Planting Program, also under the Clarke-McNary Act, helps the State Forester to provide nursery stock at a nominal cost for forest and windbreak planting and for reforestation and erosion control projects under other Cooperative State-Federal Forestry Programs.

For California in 1969, costs of operating the State's three tree nurseries were shared as follows: Federal -- $3,000, State -- $20,789, and sales to private landowners -- $53,580. Cost-sharing on trees and planting is not available to private landowners under this program, but can be obtained under the Agricultural Conservation Program, as previously described.

The Cooperative Fire Control Program provides the framework for excellent cooperation between fire control agencies, and fire damage is held to a minimum. This is expected to continue as the use of the basins becomes more intensive. The other programs are not used as extensively as they should be, probably because they must be initiated by landowners, who often are not aware of the programs. These technical assistance programs would supplement some of the direct assistance programs to landowners.

NATIONAL FOREST DEVELOPMENT AND MULTIPLE-USE PROGRAMS

Approximately 1,069 square miles of the basins are within two National Forests: Mendocino, with headquarters in Willows, covers the upper portions of the Middle Fork Eel River and of the Main Eel River; Six Rivers, headquartered at Eureka, encompasses the headwaters of the North Fork Eel River, of the Van Duzen River, and of the Mad River.

Prior to the passage of the Multiple Use--Sustained Yield Act (Public Law 86-517) on June 12, 1960, national forests were managed under several Federal statutes, principally the Organic Act of June 4, 1897, as amended. Regulations and policies promulgated by the Secretary of Agriculture and the Forest Service implemented the various statutes.

Although the principles and concepts of multiple-use management were developed before the passage of the Multiple Use--Sustained Yield Act in 1960, the act provided a congressional mandate for this type of management and was a landmark step in the history of orderly development and proper management of water and land resources of the Federal lands. Under this law, the Forest Service is directed to manage the national forests for outdoor recreation, range, timber, water, wildlife, and fish purposes.

To implement the provisions of this act, multiple-use management guides were prepared for each Forest Service region. In the guides for the Mendocino and Six Rivers National Forests, six management zones are delineated and management direction provided for each; these are the coast, general forest, front, travel influence, water influence, and special zones. Using the principles outlined in these guides, multiple-use plans have been developed for each ranger district to provide management direction for the District Rangers and their staffs. Within the framework of the multiple-use plan, functional plans are written to cover the development and use of each resource, and these provide day-to-day guidance for management.

For the portions of the two national forests in the Eel and Mad Basins, multiple-use and functional plans outline the following guidelines for the development and use of each resource:

<u>Recreation</u> -- There are presently about 300 acres developed for intensive recreation use, mainly camping and picnicking, with a capacity for serving

over 3,000 people per day. Plans are made that will provide facilities to keep abreast of future needs.

Range -- About 20 percent of the national forest land is suitable for grazing. Intermingled private lands are managed for grazing in conjunction with the national forest land. Together, they have a present grazing capacity of close to 20,000 animal-unit-months.

Objectives of management are to maintain or improve productivity on areas that are presently in a satisfactory condition and to rehabilitate and increase productivity on lands presently in an unsatisfactory condition.

Methods to be used include:

1. Keeping management plans current for all allotments.

2. Making the necessary adjustments to bring stocking in balance with forage production.

3. Converting all suitable brushfields to grass for greater productivity.

4. Constructing necessary fences, watering facilities, and other measures to obtain the optimum distribution of livestock and proper utilization of the resource.

Timber -- The Forest Service attempts to supply an annual harvest of the maximum amount of timber products consistent with the perpetuation of the resource on a sustained yield basis. In the Eel and Mad Basins, an average of about 7,200 acres is harvested within the national forests each year. Additional acreage is harvested where salvage is necessary in the wake of wildfire, insect infestation, or disease attacks. Specific measures to protect the timber resources while maintaining or enhancing productivity are:

1. To intensify management on all areas capable of producing timber in commercial quantities.

2. To reforest approximately 25,000 acres of brushfields that are capable of growing timber.

Water -- Two basic objectives of national forest management are: (1) to protect watersheds by soil stabilization and thereby preserve water quality and (2) to increase the quantity of water. The program for achieving these objectives in the Eel and Mad River Basins involves:

1. The completion of soil surveys of national forest land, which will help land managers make proper decisions regarding the resources being developed.

2. The stabilization of 76 miles of gullies.

3. The control of sheet erosion on 742 acres.

4. The stabilization of 73 miles of streambanks and lakeshores.

5. The treatment for erosion control of 162 miles of abandoned roads and trails.

6. The restoration and rehabilitation of 19 acres that have been disturbed by mining activities.

7. The building of sediment catch basins totaling 13 surface acres to trap sediment in critical watersheds.

8. The control and abatement of biological or chemical contamination of 87 miles of stream.

9. The clearing of 121 miles of stream channels.

Wildlife and Fish -- National forest management is concerned with providing habitat for wildlife and fisheries that allow full productivity of these resources for use and enjoyment by the public. Wildlife and fishery programs are coordinated with the California Department of Fish and Game because it has the responsibility for regulation and management of these resources. Wildlife habitat and fisheries improvement programs for the national forests include:

1. The completion of management plans for all ranger districts.

2. The improvement of the food supply for deer on critical winter and summer ranges.

3. The maintenance and enhancement of fisheries on critical streams. See the stream rehabilitation measures in the above section "Water."

OTHER ACTIONS NEEDED

The previous chapter "Opportunities for Development through USDA Programs" indicates that with the present policy, these programs could accomplish about 10 percent of the recommended land treatment program under existing conditions and about 30 percent under accelerated conditions. New legislation and programs or changes in present programs will be required to complete the full land treatment program and are discussed in this chapter.

CHANGES NEEDED IN USDA PROGRAMS

Most of the recommended land treatment program could be accomplished if the following changes are made in the USDA programs:

1. Accelerate the programs by increasing appropriations to each agency involved to cover the Federal cost-share. To assure continued acceleration, appropriations should be specifically designated for the land treatment program in the basins.

2. The Secretary of Agriculture should designate an individual or agency to provide leadership at the local level to coordinate the USDA programs. This would accomplish the program in an efficient manner and prevent duplication of effort by the several agencies administering the USDA programs.

3. Increase the Federal cost-share for installing the proposed remedial measures from the present 50 percent to 80 or 90 percent. Raise the Federal cost-share to 100 percent for those measures to be applied on severely eroded grasslands, since livestock would be excluded and the land would yield little or no future income. These increases would provide a greater incentive for landowners and operators to participate. It seems only reasonable that the Federal cost-share should be increased because overgrazing has occurred for more than a century and often is not primarily the fault of present owners, and it is in the national interest to protect the scenic beauty and natural resources of this area.

4. A local association, such as a range improvement district or an association of soil conservation districts, should be formed to represent the landowners and provide the overall leadership for the land treatment program. Direct local participation will provide better opportunities for cooperation between Federal agencies and landowners and for successful completion of the land treatment program. In any association formed, ranchers should be well represented since their interests are most deeply involved.

5. Compensate landowners of severely eroded grasslands for excluding livestock from these areas. If they are compensated for property taxes and the relatively small loss of income, more landowners would participate in this portion of the program.

NEW PROGRAMS OR LEGISLATION NEEDED

New USDA programs or legislation would be another way to accomplish more of the land treatment program. The following ideas might provide a framework for formulating a new USDA program:

1. Formulate a regional program to develop and protect large regions, such as the North Coastal Area of California. Problems in flood control, fish and wildlife, recreation, and urban development would be considered in addition to those of agriculture and forestry. A regional agency under State and local leadership would be established to develop and coordinate the activities of the local people and the cooperating State and Federal agencies. This agency and its cooperators would formulate a coordinated plan to develop and protect the resources of the area, making use of private resources and existing State and Federal programs. Congress would appropriate the necessary Federal money, and the State would make a similar input of funds to cover their share. Each of the cooperating agencies would be assigned responsibility for certain functions of the plan and would be given funds by the regional agency to implement their responsibilities. Prior to starting work, detailed work plans would have to be prepared for each function or phase of work.

2. Form a council of USDA agencies to provide the overall leadership and to coordinate the activities of its agricultural and forestry programs. The council would cooperate with local associations or agencies to establish the policies and goals of the land treatment program. It would assign the responsibilities for various functions to the appropriate USDA agency and would provide the necessary funds to carry out these functions.

3. Provide a specifically funded program similar to that for the Great Plains Area that would provide for Federal-local sharing of the land treatment program costs in the North Coastal Area. A local association cooperating with the USDA agency designated to administer the program would establish the policy and goals. A treatment plan with specific time limits would be developed for each property by the owner and the two groups. Prior to starting the work, a contract between the owner, the local association, and the USDA agencies would be signed, assuring that the necessary amount of Federal funds would be made available to landowners during the agreement period.

The present USDA programs with proposed changes or the recommended and new programs could accomplish most of the land treatment program. Since there are always a few individuals that will not participate, voluntary programs like these cannot be fully successful, regardless of the incentives provided. To fully accomplish the objectives of the land treatment program, restrictive legislation would be necessary, although this approach may be politically unacceptable. Some possible actions would be to:

1. Enact State or local laws requiring landowners to protect the soil and vegetal resources on their land, with stiff penalties for failure to adhere to the laws.

2. Purchase the land or property rights from the present owners, under condemnation proceedings if necessary, and resell or lease them with appropriate controls on their development and use.

A D D E N D U M

S P E C I A L   S E D I M E N T   S T U D I E S

Two special sediment studies were made to check the reasonableness of field estimates of sediment yield. Sediment deposition in three reservoirs was measured, and this data was compared with field sediment data collected from the upstream watershed area. Suspended sediment data from nine gaging stations in the Eel and Mad River Basins were analyzed and interpreted. The measured sediment data serves as a comparability check for the field estimates. This measured data can also be used for estimating sediment yield for any desired period of time during which flow records are available.

RESERVOIR SEDIMENT SURVEYS

LOCATION

Sediment surveys were made on three reservoirs in the Eel and Mad River Basins--Lake Pillsbury, Walker Lake, and Morris Lake. Lake Pillsbury is about 20 miles east of Willits on the upper Eel River, Walker Lake is about 6 miles south of Willits on Walker Creek, a tributary of the Russian River; and Morris Lake is about 3 miles southeast of Willits on Davis Creek, a tributary of the Eel River. Pertinent data regarding the reservoirs and the surveys are shown in the table on the next page. A map showing the location of the three reservoirs and the nine suspended sediment gaging stations is on the page following the table.

PROCEDURES

Morris and Walker Lakes were surveyed by the range method, which consists of laying out a system of representative ranges (cross-section lines) and determining the present water and sediment depths at regular intervals along the ranges.

Water depths are measured by sounding with a metallic tape, and the thickness of sediment deposits are measured by penetration with a sampling spud.

Lake Pillsbury was surveyed using the contour method by making soundings and plotting a contour map of the present bottom. An accurate contour map of the original bottom is essential. Sediment deposits are computed by subtracting the present water storage capacity from the original.

Both survey methods require that samples of reservoir sediment be collected and that the dry unit weight of the sediment samples be determined. The sediment sample data were weighted according to the volume of sediment they represented, and the average dry unit weight was computed for each reservoir.

Trap efficiency of Pillsbury, Walker, and Morris Lakes was obtained from a graph developed by Brune[1/] from measurements of trap efficiency on 44

1/ Gunner H. Brune, "Trap Efficiency Reservoirs." American Geophysical Union Transactions, vol. 34, No. 3, pp. 407-418. (1964).

Reservoir Sedimentation Data

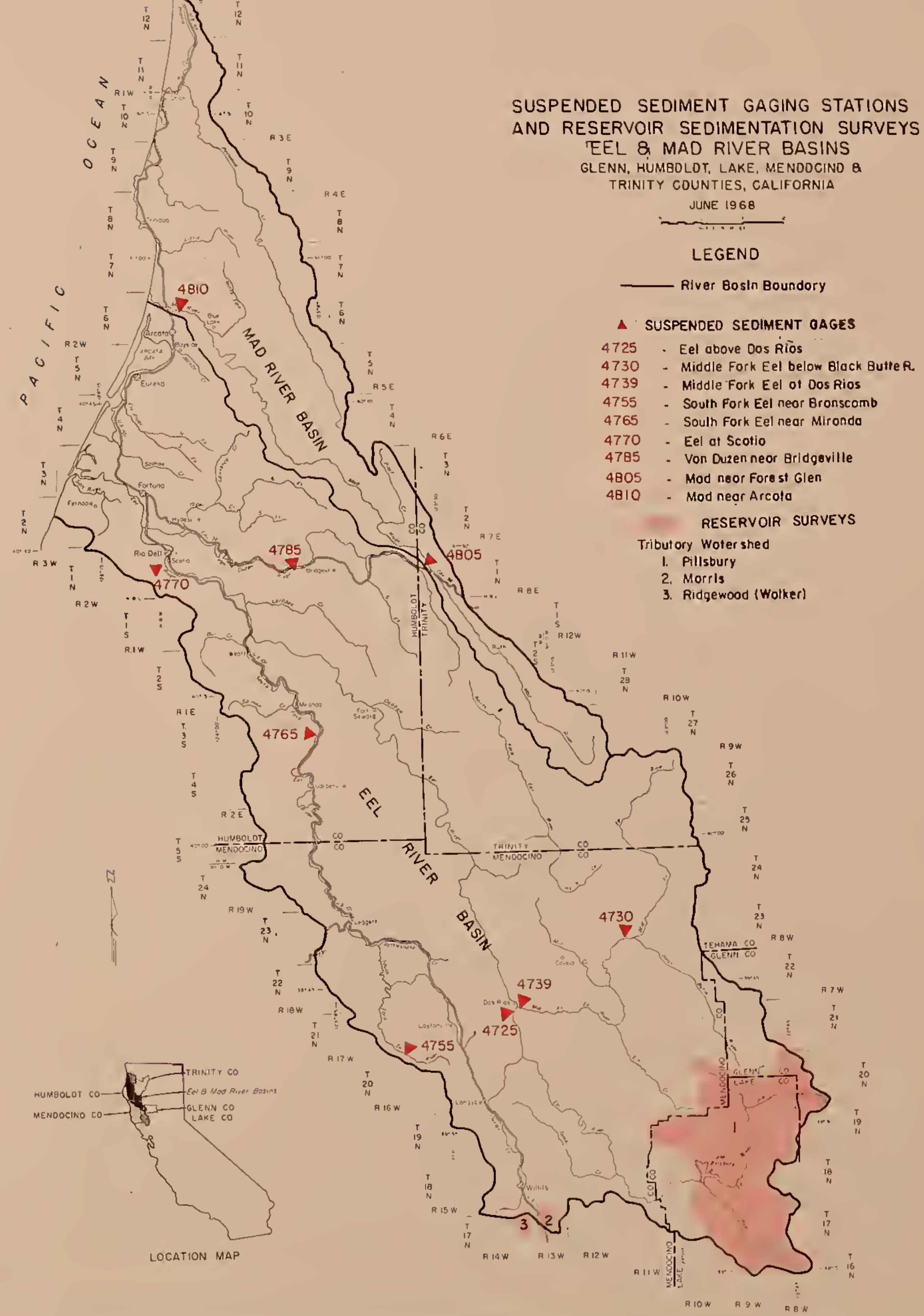
	Item	Unit	Reservoir Morris	Walker	Pillsbury
1.	Year constructed	-	1924	1930	1921
2.	Year surveyed 1/ " " " "	-	1949 1960 3/ 1966	1949 1966	1959 2/
3.	Age of reservoir (latest survey)	Years	42	36	37.5
4.	Reservoir capacity (latest survey)	Acre-feet	643	216	86,780
5.	Drainage area	Sq. Miles	5.1	5.7	288
6.	Dry unit weight of reservoir sediment	Lb./Cu.Ft. (Tons/Acre-Ft.)	50 (1,089)	78 (1,699)	73 (1,590)
7.	Trap efficiency	Percent	89	74	90
8.	Ann.sed.accum.in reservoir (survey)	Acre-Ft./Yr.	3.1	3.6	271 4/
9.	Ann.sed.yield per watershed (Item 8 ÷ Item 7)	Acre-Ft./Yr.	3.5	4.9	301
10.	Ann.sed.yield	Acre-Ft./Sq.Mile	0.69	0.86	1.04
11.	Ann.sed.yield	Tons/Sq.Mile	751	1,461	1,654
12.	Ann.sed.yield (field estimate)	Acre-Ft./Yr.	2.7	4.0	320
13.	Comparison check (Item 12 ÷ Item 9)	Ratio	0.77	0.82	1.06

1/ Unless otherwise noted, surveys were conducted by SCS.

2/ G. Porterfield and C. A. Dunnam, Sedimentation of Lake Pillsbury; Lake County, California, U. S. Geologic Survey Water-Supply Paper 1619-EE. (Washington, U. S. Government Printing Office, 1964). 46 pp.

3/ Surveyed by the Pacific Gas and Electric Company, San Francisco, California.

4/ The 1959 survey showed an average annual accumulation of 203 acre-feet per year for the 1921-1959 period; 271 acre-feet per year is an adjusted volume for the 1941-65 period.



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reservoirs. This graph relates trap efficiency to a ratio of reservoir capacity and average annual inflow into the reservoir and indicated trap efficiencies of 89, 74, and 90 percent for Morris Lake, Walker Lake, and Lake Pillsbury, respectively. These percentages were used to determine the total sediment yielded by the tributary watershed (Item 9).

Field estimates of sediment yield by sources were made in the watersheds above the lake. A comparison of the results of the reservoir surveys and the field estimates are shown in Item 13 of "Reservoir Sedimentation Data."

Because Lake Pillsbury was surveyed in 1959, the data does not reflect the added volume of sediment produced by the December 1964 storm, so the average annual sediment accumulation in the lake was adjusted to conform with the 1941-65 study period. The average annual suspended sediment yield for the watershed above the stream gage "Eel River above Dos Rios" was found to be higher for the 1941-65 period than for the 1921-59 period. Data prior to 1958 was extrapolated from interpretations, as explained in the section "Suspended Sediment Data" in this chapter. The average annual sediment yield passing that gage was compared to the yield for Lake Pillsbury for the 1921-59 period, and a ratio between the two was established. Using that ratio, the average annual suspended sediment yield passing gage for 1941-65 was used to project the estimated yield for Lake Pillsbury during that period. The average annual sediment yield for Lake Pillsbury was determined to be 271 acre-feet per year. For the earlier period (1921-59), the survey by the USGS showed an average annual accumulation of 203 acre-feet per year.

FINDINGS

The table shows that the total sediment production of these watersheds can be estimated with reasonable accuracy. As shown by Item 13, the field estimates of sediment yield (Item 12) ranged between 6 percent over and 23 percent under the estimates from reservoir surveys (Item 9). These comparisons tend to confirm the reliability of the field estimating procedure.

COMPARISON OF DATA FROM MORRIS AND WALKER LAKES WATERSHEDS

The watersheds are located near Willits and are only about 1½ miles apart. Both watersheds are about the same size and their reservoirs are about the same age. The types, distributions, and proportions of geology, soils, and native vegetation are similar. Differences between the watersheds that most affect sediment yield are rainfall, runoff, and land management.

Both reservoirs were surveyed in 1949[1/] and 1966 by the Soil Conservation Service. These surveys showed that the average annual sediment rate for

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1/ USDA Agricultural Research Service, Summary of Reservoir Sediment Deposition Surveys Made in the United States through 1960, Miscellaneous Publication No. 964, p. 52. (Washington, U. S. Government Printing Office, May 1964).

the Walker Lake Watershed (1,461 tons per square mile) was about double that for the Morris Lake Watershed (751 tons per square mile). The surveys also showed that the average annual sediment rate per square mile for both watersheds for the later period (1949-66) increased about 150 percent over the rate for the period prior to 1949. In an attempt to explain the relative overall increase in the sediment rates for the 1949-66 period, precipitation and runoff records for these two periods were analyzed. Reasons for the higher sediment rates in the Walker Lake Watershed are also suggested.

Precipitation and Runoff

Because of large storms in 1955 and 1964, the average precipitation and runoff for the period prior to 1949 was considerably less than for the 1949-66 period. The watersheds are not gaged, so runoff and rainfall were estimated using a method described by Rantz (1967)[1/]. For both watersheds, the study showed that the increase in mean annual precipitation and runoff averaged about 13 and 30 percent, respectively, from the earlier (prior to 1949) to the later period (1949-66). The study also revealed that mean annual precipitation and runoff is higher in the Walker Lake Watershed by 15 and 35 percent, respectively, than that in the Morris Lake Watershed. For both watersheds, sediment yield increased an average of 150 percent from the earlier to the later period.

Since the increase in sediment yield between the two periods was so great, a check of the suspended sediment gage data for the station "Eel River at Dos Rios" was made to find out if such increases occurred elsewhere in the Eel River Basin. The gage monitors a watershed area of 703 square miles and includes the Morris Lake Watershed. The gage data shows that suspended sediment yield increased from an average annual rate of 1,795 tons per square mile per year for the period prior to 1949 to 4,470 tons per square mile per year for the period after 1949, an increase of 150 percent. Therefore, the 150 percent increase shown in the study of Walker and Morris Watersheds appears to be consistent with increased yield in the surrounding area.

Land Management

During the time that the reservoirs have been in operation, the Morris Lake Watershed has been carefully managed by the Pacific Gas and Electric Company and has been only lightly used since 1921. In contrast, the Walker Lake Watershed has been intensively used; the land was heavily grazed for many years, part was logged for conifer in 1955, and part was logged for oak in 1966, with little apparent regard for measures that would have protected the soil and water resources.

Other than differences in land management, precipitation, and runoff, factors affecting sediment yield are remarkably similar in the two

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1/ S. E. Rantz, "Mean Annual Precipitation-Runoff Relations in North Coastal California," U. S. Geological Survey Prof. Paper 575-D, pp. D281-D283. (1967).

watersheds. However, the sediment rate for Walker is nearly double that determined for Morris. Higher rainfall and runoff in combination with poor land management probably accounts for most of the higher sediment yield from the Walker Lake Watershed.

SUSPENDED SEDIMENT DATA

AVAILABLE DATA

Suspended sediment data has been systematically collected by the U. S. Geological Survey at ten stations in the basins, most of which began operating in October 1957. The map near the beginning of this chapter shows the location of these suspended sediment gaging stations. Streamflow data has been collected for longer periods, as shown in the table on the next page. Annual suspended sediment discharge data through 1962 has been published annually in the U. S. Geological Survey Water-Supply Papers Quality of Surface Waters of the United States, Parts 9-14. (Washington, U. S. Government Printing Office). Since 1962, the data has been published annually in the USGS report Water Resources Data for California, Water Quality, Part 2. (Menlo Park, California; USGS Water Resources Division). Flow duration data for California streams are available and were extensively used in the analyses.[1/]

PROCEDURES

Most of the suspended sediment yield is produced each year during the relatively few days of highest water discharge. Therefore, to avoid handling extensive streamflow records, the sum of the highest daily mean discharge for 3 days (not necessarily consecutive) was correlated with annual suspended sediment yield. This sampling method was used for all suspended sediment gaging stations in the Eel River Basin. In the Mad River Basin, the highest mean discharge for 7 consecutive days correlated well with annual suspended sediment discharge. The station at Scotia (3,113 square-mile watershed) was started in October 1910 and, with the exception of the period 1914-17, has had a continuous daily record up to the present. Since the Scotia station has over 50 years of records, it was selected as the base station for all correlations.

Estimates of runoff at the other gaging stations were obtained by developing a correlation between the discharges at the unknown and the Scotia stations. A regression equation was computed from the recorded data using the least squares method, and the resulting best-fitting equation was plotted on logarithmic graph paper. Runoff for the unrecorded years was estimated by entering the graph with the corresponding data from the Scotia station. The regression equations used to extend runoff data at the various gaging stations are of the form, $\text{Log } Y = a + b \log X$, where X and Y are the sums of the maximum daily mean discharge in cfs-days for the 3 highest days of the year in the Eel River Basin or the highest mean discharge during 7 consecutive days in the Mad River Basin. The coefficient of

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1/ Winchell Smith and Charles F. Hains, Flow Duration and High- and Low-Flow Tables for California Streams, Open File Report (Menlo Park, California, USDI Geological Survey, 1961). 600 pp.

Mean Annual Sediment Discharge
for the 24-Year Period (1941-65)

For Total Drainage Area

Station	Period of Record by Water Years 1/		Drainage Area	Suspended Sediment		With Bedload est. + 15%	Volume in Acre-Ft./Yr.	
	Water	Sediment	(Sq.Miles)	Per Sq.Mile (Tons/Yr.)	Total (Tons/Yr.)	(Tons/Yr.)	Lost from Watershed	Deposits in Reservoir 5/
Lake Pillsbury	--	1921-59	288	1,636	471,304	542,000	271	341
Eel above Dos Rios	1951-65	1958-65	703	1,939	1,363,117	1,567,585	784	986
Middle Fork Eel below Black Butte River	1952-65	1963-65	367	2,802	1,028,334	1,182,584	591	744
Middle Fork Eel at Dos Rios	2/	1958-65	753	3,785	2,850,105	3,277,621	1,639	2,061
South Fork Eel near Branscomb	1947-65	1958-65	43.9	1,749	76,781	88,298	44	56
South Fork Eel near Miranda	1940-65	1958-62	537	3,874	2,080,338	2,392,389	1,196	1,505
Eel at Scotia	1911-65	1958-65	3,113	6,936	21,591,768	21,807,686 3/	10,904	13,716
Van Duzen near Bridgeville	1951-65	1956-65	214	6,019	1,288,066	1,481,276	741	932
Mad near Forest Glenn	1954-65	1957-65	144	827	119,088	136,951	68	86
Mad near Arcata	1951-65	1958-65	485	4,694	2,276,590	2,618,078	1,309	1,647

For Net Drainage Area 4/

Station	Drainage Area (Sq.Miles)	Per Sq.Mile (Tons/Yr.)	Total (Tons/Yr.)	With Bedload est. + 15% (Tons/Yr.)	Lost from Watershed	Deposits in Reservoir
Lake Pillsbury	288	1,636	471,304	542,000	271	341
Eel above Dos Rios	415	3,285	1,363,117	1,567,585	784	986
Middle Fork Eel below Black Butte River	367	2,802	1,028,334	1,182,584	591	744
Middle Fork Eel at Dos Rios	386	4,720	1,821,771	2,095,037	1,048	1,318
South Fork Eel near Branscomb	43.9	1,749	76,781	88,298	44	56
South Fork Eel near Miranda	493.1	4,063	2,003,557	2,304,091	1,152	1,449
Eel at Scotia	1,120	13,659	15,298,208	15,451,190 3/	7,726	9,718
Van Duzen near Bridgeville	214	6,019	1,288,066	1,481,276	741	932
Mad near Forest Glenn	144	827	119,088	136,951	68	86
Mad near Arcata	341	6,327	2,157,502	2,481,127	1,241	1,560

1/ A water year is the 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends and includes the first nine months of that year.

2/ Discharge for this gage is obtained by subtracting the flow at "Eel above Dos Rios" (703 sq. miles) from the flow at Eel below Dos Rios (1481 sq. miles), which is not shown because it has no sediment gage.

3/ For the Scotia station, bedload was estimated at 1 percent of the suspended load, according to USGS estimates.

4/ The net drainage area is the remainder after all of the areas tributary to upstream gages have been subtracted.

5/ Sediment in a reservoir occupies more space because of bulking. See page 138 for more details.

correlation (r) ranged between 0.90 and 0.99 for the data from individual stations, indicating a high degree of correlation. The runoff records for each station were extended over the 24-year study period (1941-65) as well as for the 50-year period of record for the Scotia station.

Daily suspended sediment discharge data are available for a maximum of 8 years (1957-65) at some stations in the Eel and Mad River Basins. To compare field estimates with suspended sediment discharge data, these data also had to be extrapolated or computed for years prior to 1957.

The relationship between suspended sediment yield and water discharge was determined by the regression method. Using this method, suspended sediment yield was estimated for 50 years, the period of runoff records at the Scotia station.

At some stations where suspended sediment samples were taken only periodically, these sample data were converted to annual suspended sediment yield by using the flow-duration, sediment-rating curve method.[1/] The regression method was used to develop a graph that depicted the relationship between suspended sediment and runoff. Annual suspended sediment discharge was determined by using this graph, known as a sediment-rating curve, in conjunction with a flow-duration curve for each year in which periodic samples were taken. This allowed the sediment discharge data to be extended over the 24-year base period in the manner described in the previous paragraph. The regression equations are of the form, $\text{Log } Y = a + b \text{ Log } X$, where Y is the suspended sediment yield in tons per square mile per year, and X is the sum of the maximum daily mean discharge in cfs-days for the 3 highest days in the year for the Eel Basin or the highest mean discharge for 7 consecutive days in the Mad Basin. The coefficient of correlation (r) ranged from 0.90 to 0.99 for the data from individual stations, indicating a high degree of correlation.

Using regression equations, comparisons were made between computed and measured suspended sediment loads for the 8-year period of record, and the difference in results was within 1 to 9 percent.

The procedures are further explained through the following example for the suspended sediment station "Middle Fork Eel at Dos Rios" (753 square miles).

Although there is no stream gaging station at Dos Rios, the runoff can be computed by subtracting the flow measured at the station "Eel River above Dos Rios" (703 square miles) from the flow measured at the station "Eel River below Dos Rios" (1,484 square miles). Since the remaining drainage area (781 square miles) is within 4 percent of the Middle Fork drainage area, no adjustment was made in the runoff records. Because flow records were started in 1911 at the Scotia gaging station and in 1951 at the two stations above and below Dos Rios, runoff records for the latter stations

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1/ Carl R. Miller, Analysis of Flow-Duration, Sediment-Rating Curve Method of Computing Sediment Yield. (Denver, Colorado, USDI Bureau of Reclamation Hydrology Branch, April 1951). 55 pp.

were extended by correlating with the long-term Scotia gaging station. The resulting regression equation is Log Y = -0.95213 + 1.05134 Log X, where X and Y are the sum of the 3-day maximum daily mean discharges at the stations "Eel River at Scotia" and "Middle Fork Eel at Dos Rios," respectively. The coefficient of correlation (r) is 0.96. The regression equation was used to extend the Middle Fork discharge records to the 24-year (1941-1965) base period.

The sediment records were extended by correlating the sum of the 3-day maximum daily mean discharge in cfs-days with the total annual suspended sediment load in tons per square mile measured at the Dos Rios sediment gage. The correlation coefficient (r) is 0.98, and the regression equation is Log Y = -4.84312 + 1.67405 Log X, where Y is the suspended sediment yield in tons per square mile per year and X is the sum of the 3-day maximum daily mean discharge. The data developed for the Middle Fork gaging stations from these equations are shown in the table on the next page, and the curves used in the analysis are shown in the figures on the pages following.

Total suspended load for the 24-year period is about 68,400,000 tons. During the 1965 water year, about 18,700,000 tons, or about 27 percent of the 24-year total, passed the station at Dos Rios. Suspended sediment discharge per square mile for the 1965 water year was about 6.5 times the 24-year mean of 3,785 tons per square mile per year. During water year 1956, another exceptionally large flood-year, the subbasin yielded about 4 times the 24-year mean, or about 17 percent of the total. These two flood-years accounted for about 44 percent of the total suspended sediment yield in the Middle Fork Subbasin in the 1941-65 study period.

The table shows suspended sediment only. To estimate total sediment yield, bedload must also be considered and, since bedload measurements were not available, estimates were used. Based on methods described by Sheppard (1963)[1/], bedload was estimated at 15 percent of the suspended sediment. Thus the total load is 3,277,647 tons per year during the 24-year period, and the mean is 4,353 tons per square mile per year. The data for the station "Middle Fork Eel at Dos Rios" and the other stations are summarized in the table "Mean Annual Sediment Discharge for the 24-Year Period (1941-65)" near the beginning of this section.

In this table, volumes in the last two columns were computed using different unit weights. The next to the last column shows the total volume of sediment that is eroded from the watershed each year, assuming an average in-place density of 92 pounds per cubic foot. This is a weighted average density of soil samples taken by Gardner (1963)[2/] and by McLaughlin and

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1/ John R. Sheppard, "Methods and their Suitability for Determining Total Sediment Quantities." Proceedings of the Federal Inter-Agency Sedimentation Conference, 1963, USDA Miscellaneous Publication No. 970, pp. 272-287. (Washington, D. C., U. S. Government Printing Office, June 1965).

2/ Robert A. Gardner et.al., Wildland Soils and Associated Vegetation of Mendocino County, California. (Sacramento; Resources Agency of California, Cooperative Soil-Vegetation Survey Project, 1964). 113 pp.

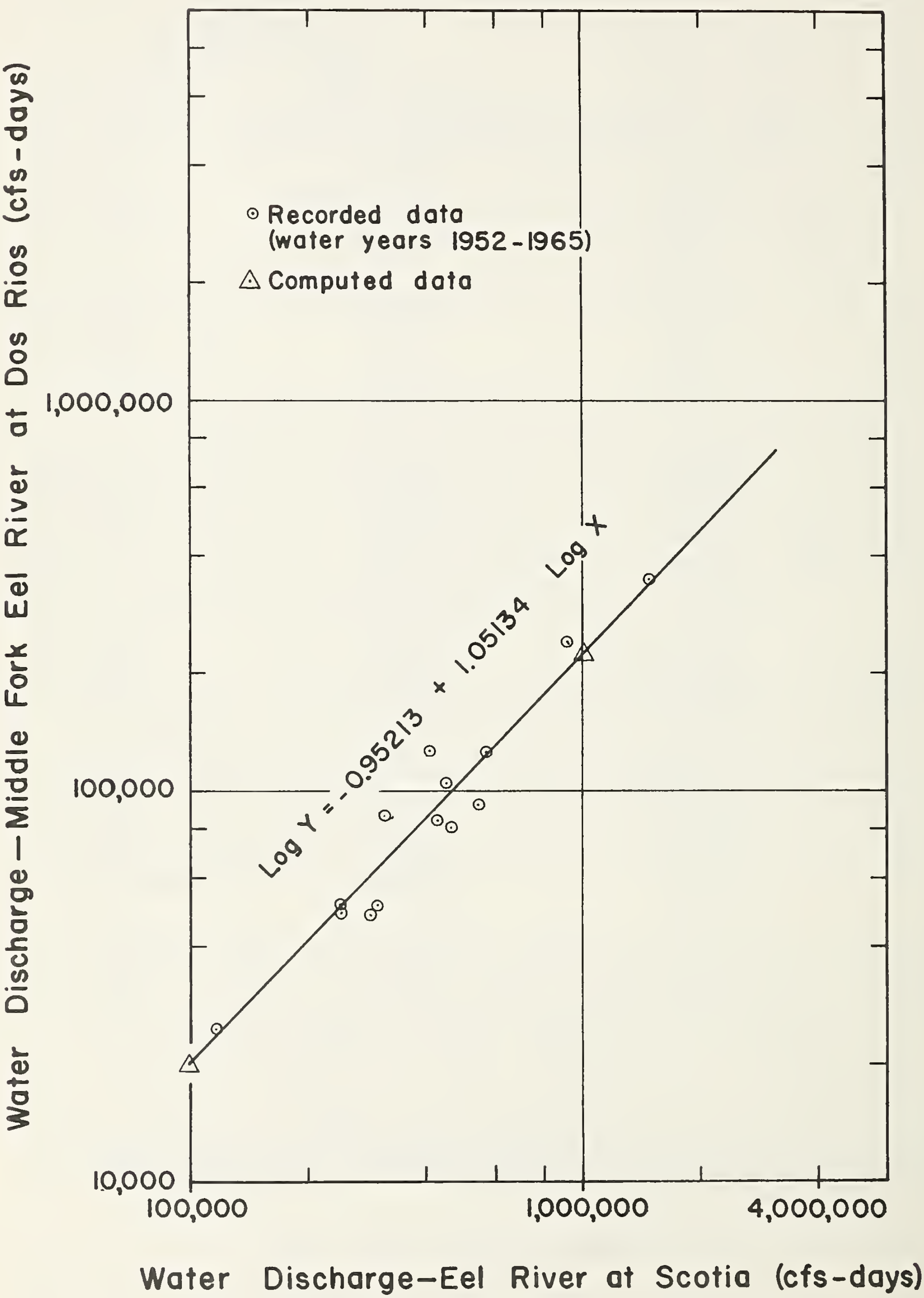
Annual Runoff and Suspended Sediment Yield
For the Station "Middle Fork Eel at Dos Rios"
For the 24-Year Period (1941-65)

Water Year	Sum of 3-Day[1/] Maximum Daily Mean Discharge (cfs - days)	Annual Suspended Sediment Yield: Per Unit Area (Tons/Square Mile/Year)	Annual Suspended Sediment Yield: Basin Total (Tons/Year)
1942	104,000*	3,600*	2,710,800*
43	115,000*	4,200*	3,162,600*
44	21,000*	245*	184,485*
45	41,000*	750*	564,750*
46	109,500*	3,900*	2,936,700*
47	34,000*	550*	414,150*
48	51,000*	1,180*	888,540*
49	63,000*	1,550*	1,167,150*
50	43,950*	840*	632,520*
51	105,000*	3,600*	2,710,800*
52	93,000	3,000*	2,259,000*
53	85,400	2,550*	1,920,150*
54	81,000	2,300*	1,731,900*
55	24,860	320*	240,960*
56	240,000	15,500*	11,671,500*
57	87,000	2,600*	1,957,800*
58	106,000	5,520	4,156,747
59	51,600	1,118	841,878
60	125,500	3,518	2,648,785
61	48,600	1,126	847,896
62	51,200	769	578,986
63	128,700	6,256	4,710,417
64	48,290	1,009	759,445
65	347,000	24,841	18,705,109
Total	2,205,600	90,842	68,403,068
Mean	91,900	3,785	2,850,128

* Data estimated from regression curves; data without asterisks is recorded.

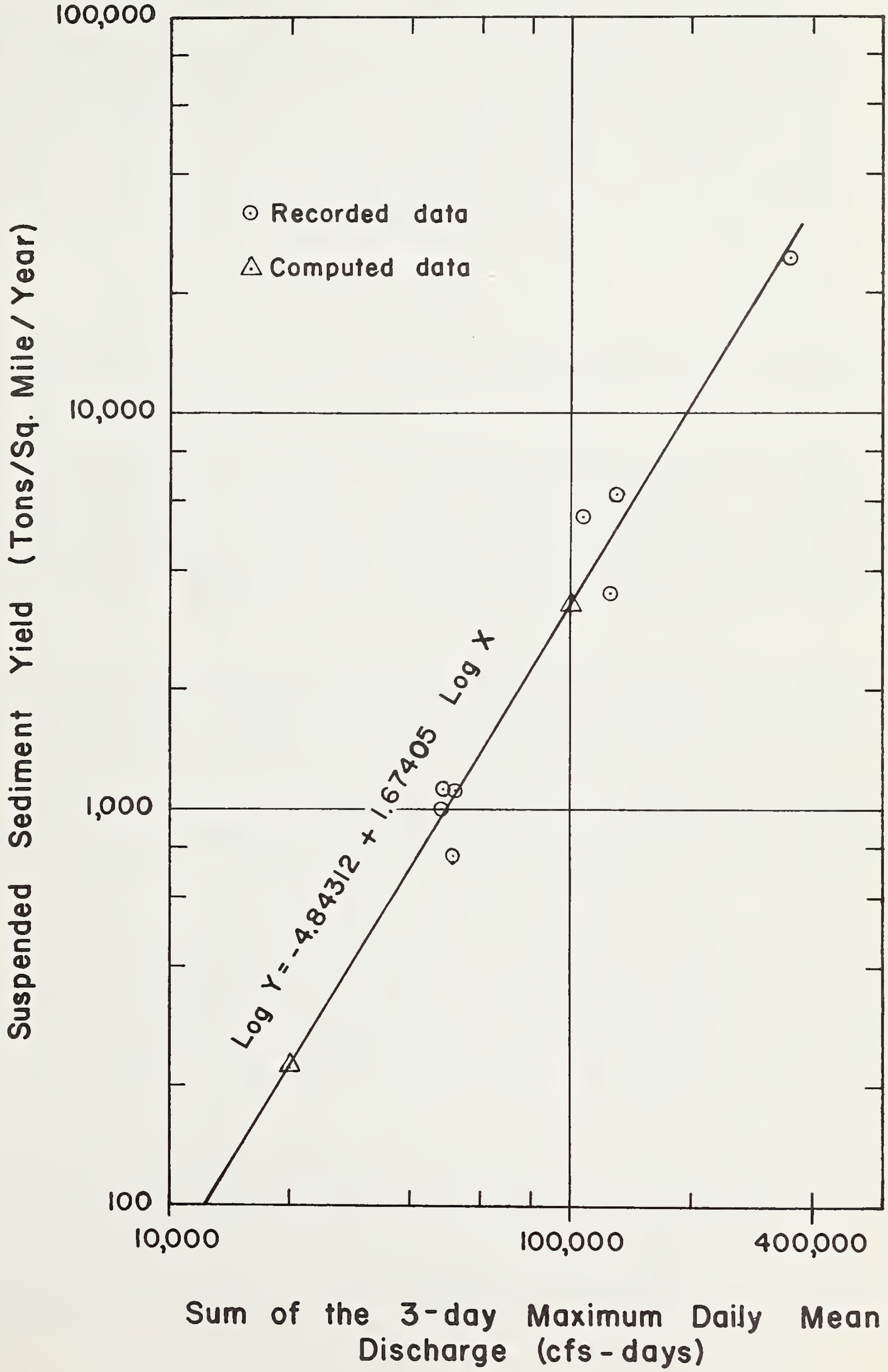
1/ This sum is the difference between flows at the stations "Eel River above Dos Rios" (703 square miles) and "Eel River below Dos Rios" (1,454 square miles).

WATER DISCHARGE - SUM OF THE 3-DAY MAXIMUM DAILY MEAN DISCHARGE (cfs-days): EEL RIVER AT SCOTIA vs. MIDDLE FORK EEL RIVER AT DOS RIOS



SUM OF THE 3-DAY MAXIMUM DAILY MEAN DISCHARGE (cfs-days) vs. SUSPENDED SEDIMENT YIELD (Tons/Sq. Mile/Year)

MIDDLE FORK EEL RIVER AT DOS RIOS



Harradine (1965).[1] Field estimates of sediment yield from landslides, streambanks, roads, and sheet and gully erosion can be compared with the figures shown in this column.

The last column presents the annual sediment rate that could be expected if a reservoir were constructed in the vicinity of the gaging station at Dos Rios. The figure reflects the effect of bulking, which is the tendency of sediment to occupy more space in a reservoir than it does elsewhere. It is assumed that sediment deposited in reservoirs planned for the basins will have characteristics similar to that in Lake Pillsbury. In a survey of Lake Pillsbury in 1959, the USGS found that the average dry unit weight of sediment was 1,590 tons per acre-foot (73 pounds per cubic foot).[2] Using this dry unit weight, the total annual yield in a reservoir at Dos Rios would be about 2,061 acre-feet per year.

INTERPRETATION OF SUSPENDED SEDIMENT GAGE DATA

Sediment discharge has been computed for all major stations and Lake Pillsbury, and all data have been adjusted to the 24-year base period, 1941-65.

About 79 percent of the Eel and Mad Basins (3,812 square miles) is monitored by suspended sediment gaging stations; the yearly sediment discharge for the monitored area is 25,156,424 tons, and the annual mean is 6,599 tons per square mile. Net annual suspended sediment yield ranges from 827 tons per square mile at the station "Mad River near Forest Glenn" (144 square miles) to 13,659 tons per square mile at the station "Eel River at Scotia" (1,120 square miles).

To show variations in sediment yield within individual watersheds, the table at the beginning of this chapter includes total and net sediment yield for all major sediment gages in the basins. Total sediment yield is all of the sediment that passes a given gaging station, and net sediment yield is the total minus that measured at all stations upstream. For example, the downstream gage ("Middle Fork Eel at Dos Rios," 753 square miles) has a total yield of 2,850,105 tons per year. The upstream gage ("Middle Fork Eel below Black Butte River," 367 square miles) yields 1,028,334 tons per year. Therefore, the net suspended sediment yield for the downstream station at Dos Rios is 1,821,771 tons per year (2,850,105 minus 1,028,334). The mean annual rate for the lower half of the watershed is 4,720 tons per square mile (1,821,771 tons divided by 386 square miles of watershed). The mean annual rate for the upstream station below the Black Butte River is 2,802 tons per square mile and for the entire Middle Fork Eel River Subbasin (753 square miles), 3,785 tons per square mile. Thus the downstream half of the watershed annually produces about 1.68

1/ James McLaughlin and Frank Harradine, <u>Soils of Western Humboldt County, California</u>. (Davis; Department of Soils and Plant Nutrition, University of California, Davis, in cooperation with the County of Humboldt, November 1965). 85 pp.

2/ G. Porterfield and C. A. Dunnam, in the work previously cited, p. 36.

times more suspended sediment per square mile than the upstream half and about 1.25 times more than the average for the entire Middle Fork Subbasin. These variations are shown in column 4 of the table "Mean Annual Sediment Discharge for the 24-Year Period" presented earlier in this chapter.

Variations in yield in the Outlet Creek-Pillsbury Subbasin are shown by the net sediment yields for the gage above Dos Rios. Lake Pillsbury traps most of the sediment produced by its watershed. This means that nearly all the sediment recorded at the gage above Dos Rios is produced by the watershed between Lake Pillsbury and the gage. The net sediment yield for 415 square miles is 3,285 tons per square mile per year, or twice that estimated for the watershed above Lake Pillsbury (1,636 tons per square mile per year). The basin average is 1,939 tons per square mile per year for 703 square miles.

Generally, in these basins sediment yield per unit area increases as the watershed size increases, as shown by the graph on the following page. In most areas of the United States, sediment yield decreases with an increase in watershed size. Eight out of ten suspended sediment load stations in the Eel and Mad River Basins have net annual yields per unit area clearly related to drainage area. The other two stations, "Van Duzen River near Bridgeville" and "South Fork Eel River near Branscomb," do not show this relationship as clearly, probably because those watersheds are in the 70- to 80-inch rainfall belt and received exceptionally heavy rainfall during the December 1955 and 1964 storms. Higher-than-normal sediment yields probably resulted from high rainfall and the resulting high runoff and high peak flows.

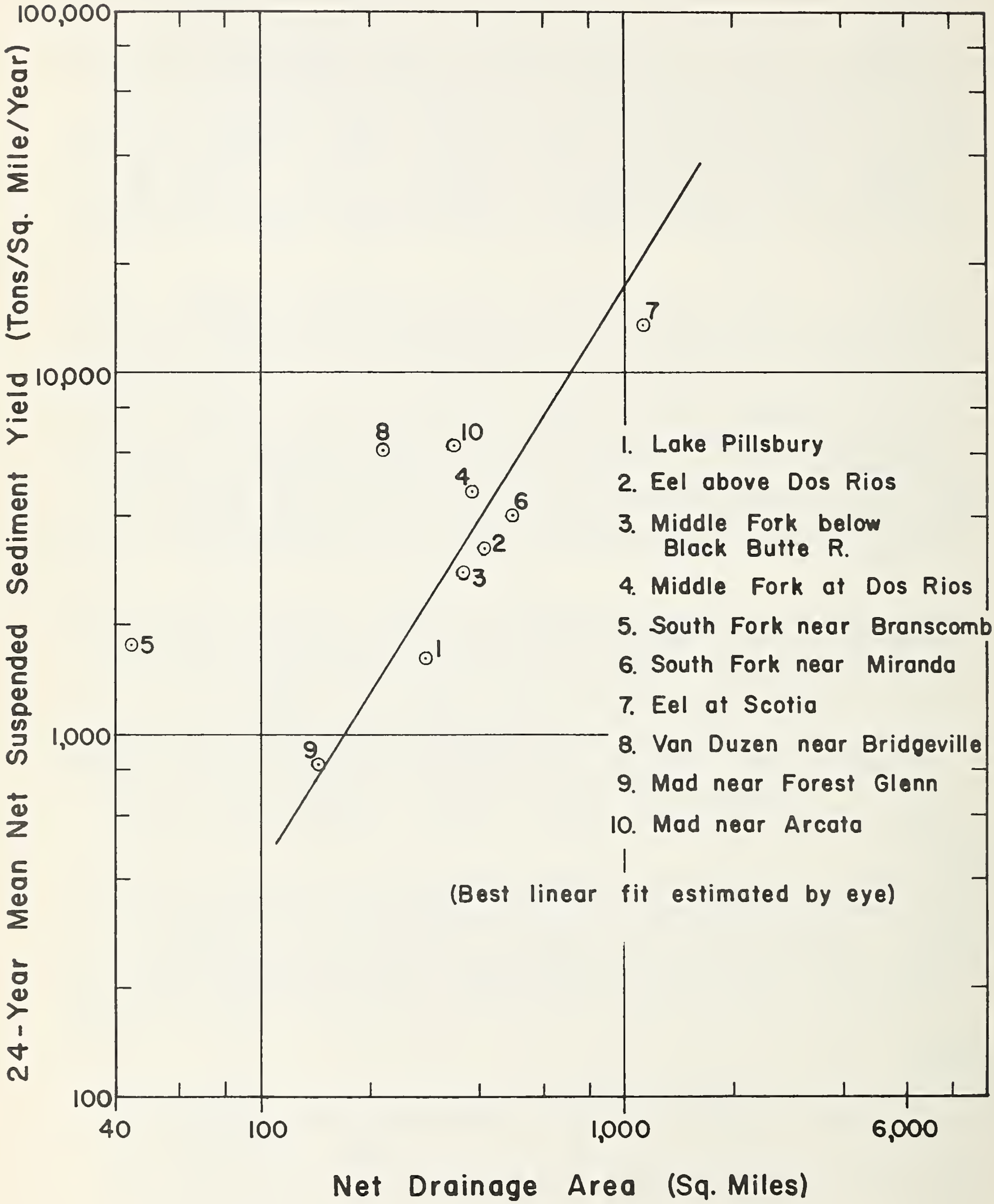
The relatively high annual net suspended sediment yield of 13,659 tons per square mile for the station "Eel River at Scotia" is apparently normal for the Eel and Mad River Basins. As the graph on the next page shows, this rate would normally be expected from an area of 1,120 square miles.

There are many factors that influence sediment yield, such as geology, soils, ground cover, land use, area and shape of drainage basin, topography, climate, and runoff. It appears that climate and runoff reflect the most change from south to north; the other factors, in general, show little change.

Precipitation and runoff increased from south to north as well as from east to west. Storms, such as those of December 1955 and 1964, generally show a similar pattern; that is, they are more severe in the western (South Fork Eel Subbasin) and northern parts (Van Duzen Subbasin and Mad River Basin) of the basins than elsewhere. Both the reservoir surveys and the sediment gage data indicate that tremendous increases in sedimentation occur during periods that include severe storms, such as those of 1955 and 1964.

Climatic factors are very influential, but they are not the only major cause of high sediment yields in the northern part of the basins. In contrast to most watersheds, the Eel River is as rugged topographically in the lower (northern) basin as it is in the upper (southern). Mountain building associated with this rugged topography and unstable geologic formations contribute an important share to the high sediment yield.

NET DRAINAGE AREA (SQ. MILES) vs. 24-YEAR MEAN NET SUSPENDED SEDIMENT YIELD (TONS/SQ. MILE/YEAR)



Impact of the December 1964 Storm on Sediment Yield

Preliminary records for the water year 1966, the first full year of record after the severe storm of December 1964, were analyzed to determine the effect of the storm on suspended sediment yield.

The sum of the 3-day maximum daily mean discharge and the suspended sediment data for water year 1966 were compared with data for the 1941-65 period. These data are summarized in the following tabulation.

Station	Sum of Maximum 3-day flows (cfs - days)		Suspended Sediment (Tons/Sq.Mile/Yr.)		Ratio (1966 to 24-Year Mean)	
	24-Year Mean	1966	24-Year Mean	1966	Water	Sedimen
Middle Fork below Black Butte River	51,933	27,850	2,802	3,058	0.54	1.09
Middle Fork at Dos Rios	91,920	98,140	3,785	5,812	1.08	1.54
South Fork near Branscomb	10,015	18,860	1,749	3,513	1.88	2.01
Eel at Scotia	413,017	593,000	6,936	9,067	1.44	1.31
Van Duzen near Bridgeville	39,747	50,100	6,090	21,829	1.26	3.58
Mad near Arcata	13,435*	15,896*	4,694	6,914	1.18	1.47
Average					1.23	1.83

* Highest mean discharge for 7 consecutive days.

The data in the table show that all but one station ("Middle Fork Eel below Black Butte River") had higher-than-average maximum 3-day flows for water year 1966. The average for all stations was about 1.23 times the 24-year mean of the maximum 3-day flows. Suspended sediment yield for 1966 averaged about 1.83 times the 24-year mean. The station "Middle Fork Eel below Black Butte" recorded about an average suspended sediment yield although the maximum 3-day flows were only half the mean for the 24-year study period. For the downstream station "Middle Fork Eel at Dos Rios," the sum of the maximum 3-day flows was about average, whereas the suspended sediment yield was 1.54 times the 24-year mean. For the station "Van Duzen River near Bridgeville," runoff in water year 1966 was 1.26 times the 24-year mean, suspended sediment was 3.58 times the mean, and the suspended sediment discharge of 21,829 tons per square mile was the highest per unit area of all the stations in the basin.

In conclusion, it appears that suspended sediment discharge in water year 1966 is greater than would be expected for given 3-day maximum daily mean flows. The increase in suspended sediment discharge probably reflects the effect of the December 1964 storm. Poor land use practices compounded the effects of the storm. As a result of the storm, raw areas exposed by new landslides and erosion of streambanks will continue to be principal sources of sediment in future years.

Runoff and suspended sediment records should be analyzed as new data is published. As the full effect of the 1964 storm becomes more apparent, large flood events, such as those in 1964 and 1955, and their effect on the watershed can be better evaluated.

Comparison of Field Estimates and Gage Data for Suspended Sediment

Sediment discharge, as determined by the field estimates, was compared to that obtained from interpretations of suspended sediment gage measurements. These comparisons show that sediment discharge can satisfactorily be predicted by the procedures used in the study. The field estimates ranged from 0.70 to 1.31 times the sediment discharge calculated from suspended sediment gage data, with an average of about 0.95 times that determined from the gage data. For 10 out of 15 stations, estimates were within a range of between 0.80 and 1.00 times that determined from the gage data. Both ranges are considered to be satisfactory for river basin surveys. The comparisons are tabulated in the table "Comparison of Field Estimates and Gage Data for Suspended Sediment Stations" on the next page.

From the above discussion, the value of using measured data such as reservoir survey data and suspended sediment gage data is obvious. Future studies of this nature should utilize measured data whenever possible.

Comparison of Field Estimates and Gage
Data for Suspended Sediment Stations[1]

Station	(1) Drainage Area (Sq.Miles)	(2) Sediment Field Est. (Acre-Ft/Yr)	(3) Discharge Gage Data (Acre-Ft/Yr)	(4) Comparison Col.2÷Col.3 (Ratio)
Eel above Lake Pillsbury	288	388	301	1.29
Eel above Dos Rios	415	644	757	0.85
Gage total	703	683[1]	787[1]	0.87
Middle Fork below Black Butte River	367	756	591	1.28
Middle Fork at Dos Rios	386	878	1,048	0.84
Gage total	753	1,633	1,639	1.00
South Fork near Branscomb	43.9	40	44	0.91
South Fork near Miranda	493.1	1,079	1,152	0.94
Gage total	537	1,119	1,196	0.94
Eel at Scotia	1,120	6,368	7,726	0.82
Gage total	3,113	9,803	10,904	0.90
Van Duzen near Bridge-ville	214	695	741	0.94
Mad near Forest Glenn	143	89	68	1.31
Mad near Arcata	342	868	1,241	0.70
Gage total	485	957	1,309	0.73
Mean for all stations				0.95

1/ Assuming 10 percent of the sediment produced by the watershed above Lake Pillsbury passes through the lake (90 percent trap efficiency).